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Managing the Nation's Commercial High-Level Radioactive Waste

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Foreword

This report presents the findings and conclusions of OTA's analysis of Federal policy for the management of commercial high-level radioactive waste. It represents a major update and expansion of the analysis presented to Congress in our summary report, *Managing Commercial High-Level Radioactive Waste,* published in April of 1982 during the debate leading to passage of the Nuclear Waste Policy Act of 1982 (NWPA). This new report is intended to contribute to the implementation of NWPA, and in particular to congressional review of three major documents that DOE will submit to the 99th Congress:

- a Mission Plan for the waste management program;
- a monitored retrievable storage (MRS) proposal; and
- a report on mechanisms for financing and managing the waste program.

The assessment was originally undertaken at the request of the House Committee on Merchant Marine and Fisheries and focused on the ocean disposal of nuclear waste. OTA later broadened the study to include all aspects of high-level waste disposal after expressions of interest and support by the Senate Committees on Energy and Natural Resources and on Commerce, Science, and Technology; by the Senate National Ocean Policy Study; and by the House Committees on Science and Technology and on Foreign Affairs. Additional requests for related analysis were later received from the Senate Committee on Environment and Public Works and from the House Committees on Interior and Insular Affairs and on Energy and Commerce. The major findings of the original analysis were published in OTA's 1982 summary report.

Following passage of NWPA, the House Committee on Rules asked OTA to analyze the Act from the perspective of the policy conclusions of our 1982 study. The major conclusion of that review, included as chapter 5 of this new report, is that *NWPA provides sufficient authority for developing and operating a waste management system based on disposal in geologic repositories.* Substantial new authority for other facilities will not be required unless major unexpected problems with geologic disposal are encountered.

In addition, the House Committees on Interior and Insular Affairs and on Energy and Commerce asked OTA to provide information on the Mission Plan required by NWPA. OTA concludes that DOE's Draft Mission Plan published in 1984 falls short of its potential for enhancing the credibility and acceptability of the waste management program. The summary of this report, included as chapter 1, presents the key findings and options concerning the Mission Plan and the other documents mentioned above.

OTA is grateful for the assistance of the advisory panel for this assessment, as well as the support and guidance received from many other people and organizations. OTA has also benefited from the full cooperation of the Department of Energy, the Nuclear Regulatory Commission, the Environmental Protection Agency, and other Federal agencies. OTA assumes full responsibility for the report.

John H. Gibbons

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Chapter 1

Executive Summary

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Chapter 1
Executive Summary

OVERVIEW

With the passage of the Nuclear Waste Policy Act of 1982 (NWPA), Congress for the first time established in law a comprehensive Federal policy for commercial high-level radioactive waste management, including interim storage and permanent disposal. **NWPA provides sufficient authority for developing and operating a high-level radioactive waste management system based on disposal in mined geologic repositories.** Authorization for other types of waste facilities will not be required unless major problems with geologic disposal are discovered, and studies to date have identified no insurmountable technical obstacles to developing geologic repositories.

The 99th Congress will receive three key documents that NWPA requires the Department of Energy (DOE) to prepare:

1. *a Mission Plan,* containing both a *waste management plan* with a schedule for transferring waste to Federal facilities and an *implementation program* for choosing sites and developing technologies to carry out that plan;
2. *a monitored retrievable storage (MRS) proposal,* with designs for long-term Federal storage facilities, evaluations of whether they are needed and feasible, and analysis of how they would be integrated with the repository program if authorized by Congress; and
3. *a study of alternative institutional mechanisms* for financing and managing the radioactive waste system, including the option of establishing an independent waste management organization outside of DOE.

Each of these documents will raise issues of potentially significant concern to Congress and the Nation.

The Mission Plan

The crucial next step for stabilizing the U.S. radioactive waste management program, and for building confidence that nuclear waste can and ultimately will be disposed of safely, is to develop a credible Mission Plan that is widely viewed as achievable and responsive to the concerns of the major affected parties. According to NWPA, the document to be submitted by DOE is intended to provide "an informational basis sufficient to permit informed decisions to be made." To do this, it must identify the key decisions in developing the waste management system, analyze and compare the technical and programmatic options, and thereby provide the information that would support DOE's choice among the options. In OTA's view, the *Draft Mission Plan* published by DOE in April 1984 does not meet this test. OTA believes that the preparation of a final Mission Plan offers DOE a major opportunity to enhance the credibility and acceptability of the waste management program.

As part of its analysis of NWPA, OTA has identified the elements of a Mission Plan that can meet the requirements of the Act using only the authority it provides. Comparison between this "OTA Mission Plan" and DOE's *Draft Mission Plan* provides a basis for identifying the major strategic decisions in the Mission Plan. Comparison also reveals several areas in which additional analysis by DOE would provide valuable information for congressional deliberations during the 30 working days that the Mission Plan lies before Congress before becoming effective. In general, the OTA Mission Plan represents an expansion, rather than a redirection, of the approach in DOE's *Draft Mission Plan.* None of DOE's ongoing repository siting or development activities need or should be deferred pending development of a final Mission Plan.

The major difference between the two Mission Plans lies in the measures used to provide confidence that spent fuel will be removed from reactor sites within a reasonable period, despite the technical and institutional uncertainties associated with siting and licensing the first geologic repository. DOE's *Draft Mission Plan* is based on a repository loading schedule that allows for no problems or delays in choosing or licensing the first repository. The repository siting program includes no backups for the sites that NWPA requires to be evaluated at key stages of the siting process. To provide confidence that waste can be accepted in the event that this siting program encounters significant delays, the *Draft Mission Plan* proposes to ask Congress for new legislative authority to site and license an MRS facility so that one could be constructed as early as 1998, if needed.

The OTA Mission Plan, on the other hand, relies on the existing authority in NWPA to the maximum extent possible. It recognizes that the first geologic repository required by NWPA is the only facility DOE is now authorized to site and use to accept high-level radioactive waste.[1] It uses a repository loading schedule that can be met despite technical or institutional difficulties, and an aggressive implementation program designed to reduce the risk of extended delays in the repository program. In particular, it adds one backup site to those required by NWPA at critical siting steps. The OTA Mission Plan would ask for new legislative authority to construct MRS facilities or alternative disposal facilities only as a last resort, if major problems call into question the feasibility of geologic disposal.

The repository program in the OTA Mission Plan differs from that in DOE's *Draft Mission Plan* in three key respects: the repository loading schedule, the repository siting strategy, and the strategy for developing the first repository. The issues in these areas are discussed in the remainder of this section; issues concerning the role of the MRS are discussed in the following section, which deals with the separate MRS proposal required by NWPA.

Repository Loading Schedule

A schedule for loading the geologic repositories is needed as a basis for contractual commitments by DOE to accept waste from utilities. The crucial decision concerning the repository loading schedule is the balance between the degree of certainty that the schedule can be met, and the promised speed of the schedule. The more optimistic the schedule for contractual commitments, the more likely it will be that they cannot be met using the first geologic repository, and that other means will be needed to meet Federal obligations. DOE's *Draft Mission Plan* uses an optimistic repository schedule that can be met only if no significant delays are encountered. If all goes well, loading at the repository (using limited packaging facilities) would begin by 1998, the year in which NWPA requires initial disposal in the first repository. Operation of full-scale facilities would begin by about 2001. DOE does not specify when loading might begin if there are problems or delays.

The OTA Mission Plan also uses the 1998 target as a management goal for initial disposal of a small amount of waste packaged during the technology development program. However, it bases contractual commitments with utilities on a conservative schedule for full-scale repository operation. This loading schedule can be met despite the delays that can be expected in the effort to site the first repository. Specifically, **OTA concludes that use of an aggressive implementation program (discussed below) can give considerable confidence that the two repositories required by NWPA can be operating full-scale by 2008 and 2012, respectively, even if significant delays are encountered.** If such delays do not materialize, full-scale loading could begin years earlier, and the actual schedule could match that proposed by DOE.

Repository Siting Program

The credibility of any repository loading schedule depends on the credibility of the implementation program supporting it. The major decision concerning the implementation program is the balance between the initial costs of the program and the certainty of getting the job done without major problems or delays. This is particularly important in the repository siting program.

DOE's *Draft Mission Plan* uses a reactive approach in its implementation program. In particular, the siting program considers only the number of sites required by NWPA: that is, for each repository, three sites would be investigated at depth ("characterized"), and one site would be recommended for licensing. Backups would be developed only *after* it is certain they are needed. This strategy is unchanged from the one in use before the NWPA made a commitment to a schedule for operation of a repository.

---

[1] NWPA requires DOE to site and license a second repository, and limits the amount of waste that can be emplaced in the first before the second begins operating. NWPA does not explicitly authorize construction of the second repository.

By contrast, the OTA Mission Plan uses a preventive approach involving development of backup sites before they might be needed, to minimize the delays that could result if there are difficulties with the primary candidate sites. In particular, it provides for characterization of four sites, and recommendation of two for licensing, for each repository.

Adding one backup to the number of sites NWPA requires at each stage significantly reduces the risk that the siting process will be delayed by problems at any one site. This approach may cost more at the start, but over the long run its financial and political costs may well be less than those of a program that makes no allowance for major delays or problems. Among those potential costs is the risk that programmatic failures could damage the credibility of the Federal program. Thus any extra initial costs can be seen as the price of insurance against these difficulties. Congress may therefore wish to ask DOE to analyze the additional cost of this approach, if any, and its effectiveness in raising the confidence of the proposed repository loading schedule.

Technology Development Plan

In DOE's *Draft Mission Plan,* the schedule for developing the final designs for the repository and waste package is driven by the optimistic repository loading schedule, which requires rapid construction of packaging facilities at the site after the Nuclear Regulatory Commission (NRC) construction authorization is granted. This approach makes initial disposal dependent on the construction schedule of the packaging facilities. The pressure to complete those facilities in time to meet the 1998 deadline may preclude use of one of the new integrated system designs now under development that have the potential for significantly reducing the costs and impacts of waste management.

To avoid this potential problem, the OTA Mission Plan suggests that the first repository be developed in two phases. A *small-scale demonstration phase* would begin as soon as allowed by NRC following its approval of a construction authorization. This would involve licensed emplacement of a small amount of waste packaged during the repository research, development, and demonstration (RD&D) program using a *conservative system design*, one that emphasizes certainty in meeting NRC's requirements for disposal, rather than overall efficiency of waste management operations.

The *full-scale operational phase* would begin after the development and licensing of an *integrated, optimized system design* that takes advantage of the most advanced available technology to reduce the risks, costs, and impacts of the entire waste management operation, from discharge of spent fuel from the reactor to final disposal in a repository. Planning for initial licensed disposal before the repository's own packaging facilities are constructed maximizes the likelihood that the 1998 deadline will be met, and allows the schedule for construction of those facilities to be determined by the time required for an aggressive RD&D program to develop the integrated system design.

The Monitored Retrievable Storage Proposal

It now appears that MRS facilities will not be necessary for safe waste management. NWPA requires that the utilities themselves provide interim spent fuel storage until a repository is available. This storage can probably be provided at reactor sites, even after the 1998 deadline. OTA's Mission Plan provides for MRS facilities to be available as a long-term backup to repositories, **but only in the event that major unanticipated difficulties are encountered with geologic disposal.**

The major storage issues to be addressed in both the Mission Plan and the MRS proposal are *when* and *whether* DOE should be authorized to construct a centralized MRS facility, and *what role* it would play in the integrated waste management system. OTA's analysis suggests that, to aid congressional deliberations, the MRS proposal submitted by DOE should evaluate at least three alternatives:

1. **Early siting, licensing, and construction of an MRS facility.** This option, which is implicit in DOE's *Draft Mission Plan,* would re-

quire congressional authorization in the near future. It would allow DOE to accept waste on a large scale beginning in 1998, even if there are delays in the repository program. It involves a commitment of additional manpower and resources over the next decade, above and beyond those already involved in the repository siting process.

2. **Federal at-reactor storage beginning in 1998.** This might be accomplished through rulemaking, by modifying contracts with utilities to provide that the Federal radioactive waste program would pay the costs of additional storage beyond the contractual delivery date, thus spreading the costs of delays in the repository program among all utilities paying the waste disposal fee. If so, no congressional action would be required.
3. **Deferral of the decision on a centralized MRS facility until at least 1990, when the first repository site is to be recommended to Congress.** This allows the decision to be made based on much more information about storage options, integrated waste management system designs, and the progress of the repository program than is currently available. It also avoids the risk that an early effort to site a large-scale storage facility would delay the repository program. This option would require no congressional action at this time.

Alternative Means of Financing and Management

NWPA also requires DOE to submit a study of alternative institutional mechanisms for financing and managing the radioactive waste system, including the options of an independent agency or even a private corporation. A public advisory committee established by DOE to address this subject recommended consideration of a federally chartered public corporation. **OTA's analysis suggests that the credibility of NWPA's commitment to the development of a first-of-a-kind technological system on a firm schedule could be significantly enhanced by the establishment of an independent waste management agency with more funding and management flexibility than is typical in a Federal program.** The more independent the institution and its funding, the surer the guarantee that a complex program will be carried out on schedule and will not be disrupted by other fiscal or political priorities of the Federal Government.

Balancing independence and accountability is a key challenge in designing an independent waste management agency. A congressionally approved Mission Plan could serve as the principal mechanism for balancing effective congressional control with increased flexibility of operation. In fact, it may not be possible to gain broad support for the creation of an independent institution with independent funding *until* a generally accepted Mission Plan—one that spells out exactly what the agency is to do—is developed. If it were formally approved by Congress, the Mission Plan could serve as the main yardstick for overseeing the activities and expenditures of the waste management agency and for measuring its progress. Since approval of the Mission Plan is not now required by NWPA, consideration of mechanisms for such approval might be included in any congressional deliberations on establishing an independent waste management agency.

BACKGROUND

When the 97th Congress began considering comprehensive waste management legislation in 1981, there were 74 commercial nuclear powerplants in operation in the United States, and some 85 additional plants were under construction. Approximately 8,000 metric tons (tonnes) of commercial spent (used) nuclear fuel, containing highly radioactive waste products, had already been generated. Yet the United States still had not decided how to deal with the problem of isolating those waste products from the environment for the thousands of years required for the radioactivity of the waste to decay to low levels.

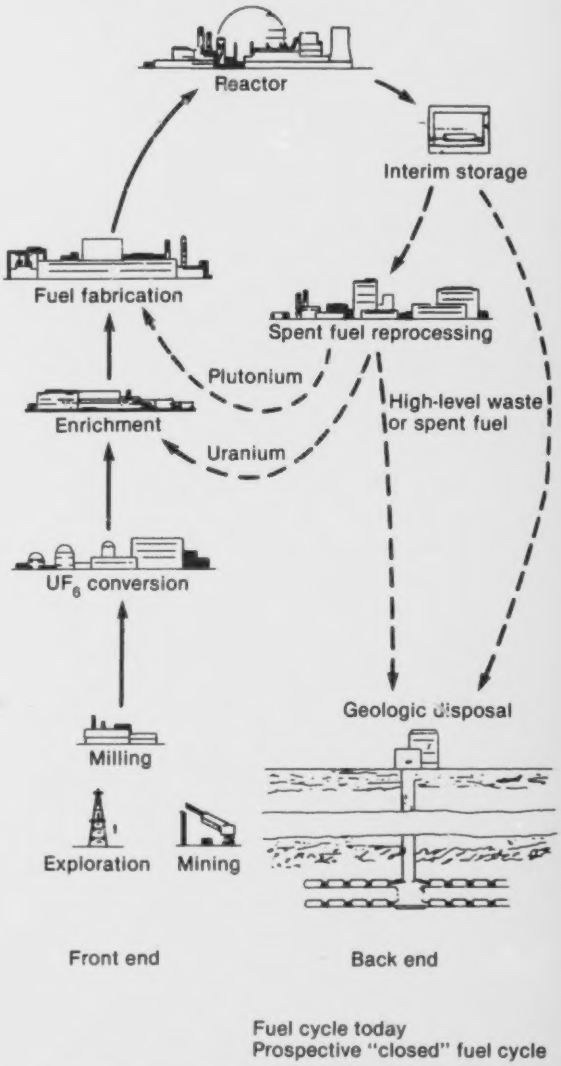
Nearly all of the spent fuel produced thus far by commercial nuclear powerplants is temporarily stored in water-filled basins at operating reactors. The original expectation—that all spent fuel would be reprocessed to recover usable uranium and plutonium, and that the radioactive byproducts would be separated as high-level waste—has not been realized. It now appears possible that much of the spent fuel will be discarded directly as waste (see fig. 1-1).

The lack of final isolation facilities raised two key problems for the nuclear industry. First, some critics questioned the continued use of nuclear power, arguing that the failure to develop final isolation facilities was evidence that waste isolation might be an insoluble problem. Second, the lack of reprocessing or disposal facilities to accept spent fuel left utilities that owned nuclear reactors with a growing spent fuel storage problem. In the near term, operating reactors were running out of storage space, and some faced the possibility of having to shut down unless additional storage capacity were made available in a timely manner. In the longer term, the absence of a firm schedule for either reprocessing or turning spent fuel over to the Federal Government left utilities uncertain about how much additional storage capacity they would have to provide, when they would end their liability for growing inventories of spent fuel, and how much storage and disposal would ultimately cost.

The storage problem was complicated by increasing opposition to the efforts of utilities and the Federal Government to provide additional storage capacity. This opposition resulted from concern that the easy availability of interim *storage* would reduce the pressure for developing a Federal *disposal* system, thereby turning interim storage facilities into de facto permanent waste repositories. This opposition, in turn, had increased utilities' fears that they might not be able to gain approval for additional storage facilities quickly enough to prevent reactor shutdowns.

The problems facing the nuclear industry, combined with the broader societal concern that nu-

Figure 1-1.—The Nuclear Fuel Cycle



The commercial nuclear fuel cycle includes activities for preparing and using reactor fuel and for managing spent fuel and other radioactive wastes produced in the process. It was originally intended that spent fuel be stored for 6 months in water-filled basins at reactor sites to dissipate thermal heat and allow decay of short-lived fission products. The spent fuel would then be reprocessed and the resultant liquid high-level waste solidified and disposed of in a Federal repository. Since no repository has been developed and no commercial reprocessing is being done, spent fuel will remain in storage until repositories are available to close the nuclear fuel cycle.

SOURCE: Council on Environmental Quality.

clear waste be dealt with responsibly, generated considerable pressure to proceed promptly to develop final isolation facilities. The challenge facing Congress was to develop a *comprehensive* waste management policy: one that dealt with interim storage in the context of final isolation and provided the stability of purpose and direction that had been lacking in previous Federal waste management efforts.

Earlier problems in the Federal program complicated the development of such a policy. First, some doubted that the existing Federal institutional arrangements were capable of successfully implementing waste management policy over a period of decades. Second, the distrust that had developed between the Federal Government and those States affected by waste management activities seriously complicated efforts to reach agreement on a program for siting permanent repositories. On the one hand, potential host States and other groups feared that the Federal Government might cut corners, simply to be able to say that the problem had been solved. On the other hand, some in the Federal Government feared that at least some States might seek to block any waste management activities within their borders, no matter what assurances of safety were provided.

Congress addressed all of these problems in NWPA by including measures that specify:

1. a comprehensive Federal policy for high-level radioactive waste management that spells out the responsibilities of the utilities and the Federal Government;
2. relationships between the Federal Government and the States and Indian tribes affected by waste management activities; and
3. improvements in the institutional mechanisms through which the Federal Government will carry out that policy.

These measures are summarized briefly below, as background for discussion of the issues that remain to be resolved during implementation of the Act.

THE NUCLEAR WASTE POLICY ACT OF 1982

Waste Management Policy

Final Isolation of Nuclear Waste

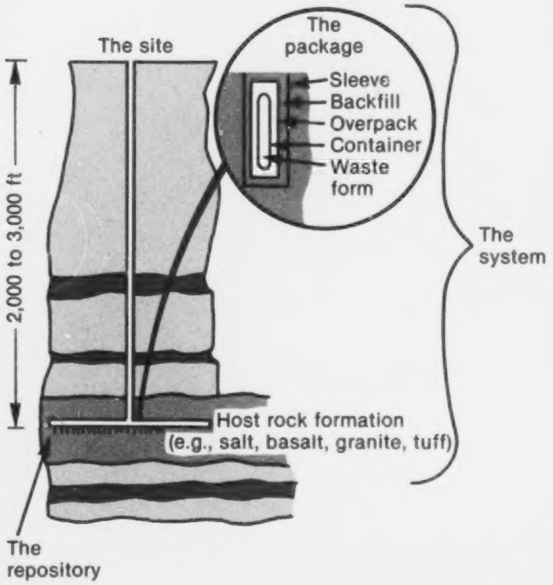
NWPA establishes a schedule for DOE to site, and for NRC to decide on licenses for, two geologic repositories (see fig. 1-2) for permanent disposal of civilian high-level radioactive waste. This schedule requires that DOE *begin* disposing of waste at the first repository not later than January 31, 1998. The repositories are to be able to handle both commercial spent fuel and high-level waste from reprocessing. They are also to be used for high-level waste from defense nuclear activities unless the President determines that separate repositories for defense waste are needed. (A draft DOE study concludes that disposing of defense and commercial wastes in the same repositories would be the most cost-effective option.)

The two repositories required by the Act appear to be both necessary and sufficient to dispose of the waste from commercial reactors that are now operating or under construction, as well as currently projected amounts of defense high-level wastes. Nearly 30 years of study have revealed no insurmountable technical obstacles to the successful development of mined geologic repositories, although suitable sites must still be found. **OTA believes that small-scale disposal could begin by the 1998 target for *initial* operation of the first repository,** if a suitable site can be selected from among those under investigation at the time NWPA was passed. (Measures to increase the likelihood of success are discussed below.) **OTA also concludes that an expanded siting and development program can give considerable confidence that the two repositories required by NWPA could be operating at full scale by no later than 2008 and 2012, respectively, even if there are major delays or if backup sites must be used.**[2]

---

[2] These dates are conservative in comparison with DOE's schedule for the second repository, which suggests that a repository using a site and a geologic medium not among those under consideration for the first repository could be available by 2005.

Figure 1-2.—Mined Geologic Disposal Concept



Mined geologic disposal will use a system comprised of engineered barriers (the waste package and the mined repository) and naturally occurring barriers (the host rock formation and the chemical and physical properties of the repository site itself) to provide long-term isolation of waste from the biosphere. Three decades of extensive study have revealed no insurmountable technical obstacles to the development of mined geologic repositories, provided suitable sites are found.

SOURCE: Department of Energy.

OTA's review of the history of the waste management program concludes that a commitment in law to a firm schedule for operation of a Federal disposal facility (as enacted in NWPA) would play a central role in a comprehensive, broadly supported waste management policy. This commitment is needed for three major reasons. First, the history of opposition to proposals for Federal *storage* facilities suggests that, to satisfy public concerns, it will be necessary to develop permanent *disposal* facilities (see box). Second, a firm and believable schedule for a repository decreases concern that spent fuel would remain in interim storage indefinitely, a major source of resistance to past efforts to provide additional interim storage. Finally, the key measures needed to give that commitment credibility (i.e., an aggressive implementation program involving backup repository sites and disposal technologies) would address a major concern about the Federal waste management program in the past—the concern that crucial decisions might be compromised by the lack of options.

Storage and Disposal: A Basic Distinction

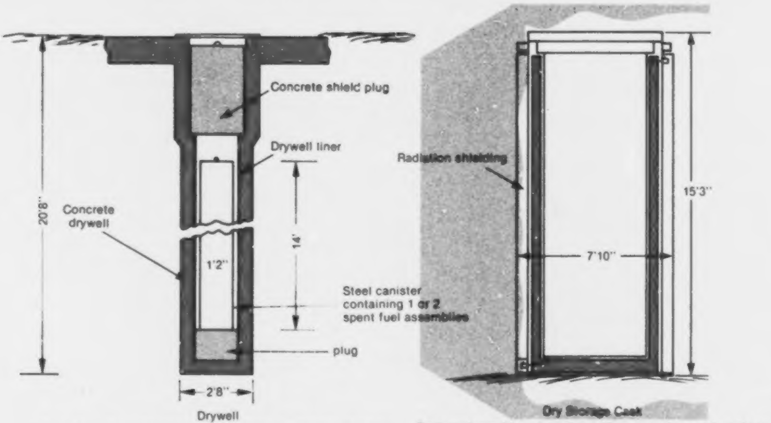
Much of the debate about radioactive waste has been clouded by blurred and shifting distinctions between **disposal** and **storage**, which are different technological approaches to the **isolation of** radioactive waste from the biosphere. Briefly, **disposal** is isolation that relies only on natural (environmental) and manmade barriers, does not permit easy human access to the waste after its final emplacement, and does not require continued human control and maintenance. **Storage** is isolation that permits easy access to the waste after its emplacement and requires human control and maintenance in order to guarantee isolation. Thus, disposal is always designed to provide final isolation (the last step in the waste management process), while storage may be intended for either final or interim (temporary) isolation. Because storage requires human control and maintenance, while disposal requires none, **disposal and storage are not synonymous terms.**

Interim Storage of Spent Fuel

NWPA gives utilities that operate nuclear reactors the primary responsibility for storing spent fuel until it can be delivered to a permanent repository. The Act also contains measures to help utilities provide such storage at reactor sites using new dry storage technologies (see fig. 1-3). DOE now expects that these measures can preclude the need to use the 1,900 tonnes of "last resort" Federal storage capacity, which the Act makes available to utilities that are unable to provide their own storage in time to prevent disruption of reactor operations.

The Act also ensures that long-term storage under active human control will be available, if needed. It requires DOE to submit to Congress a proposal for construction of one or more MRS facilities, including an analysis of the need for such facilities, their feasibility, and how they might be integrated into the waste management system. The role of retrievable *storage* in the waste management

Figure 1-3.—Dry Storage Concepts for Spent Fuel



Drywell

Each drywell would hold a steel canister containing about 0.5 tonnes of spent fuel (1 or 2 fuel assemblies depending upon the type of reactor).

Dry Storage Cask

Each cask would contain about 10 tonnes of spent fuel (24 to 52 assemblies).

If licensed, dry storage technologies like these may provide a relatively inexpensive, flexible alternative to water-filled basins for in-

There appear to be no fundamental technical questions about the ability to design, construct, and operate storage facilities for spent fuel or reprocessed waste to meet applicable radiation protection standards, as long as continuing surveillance and maintenance of the facilities is provided. Safe storage in water basins has already been demonstrated for periods of up to 20 years. New dry storage technologies (storage casks, drywells, and concrete silos) that can be added in small increments or modules as needed are potentially much more flexible, quicker to implement, and less expensive for at-reactor use than water basins.

SOURCE: Office of Technology Assessment.

system is an important issue that remains to be resolved. However, the Act requires *disposal* in geologic repositories to proceed, regardless of what is done about MRS facilities.

It now appears that MRS facilities will not be necessary for safe management of high-level radioactive waste unless major unexpected difficulties with geologic disposal are encountered. NRC has determined that spent fuel can be safely stored at reactor sites for at least 30 years after the reactor is decommissioned. Analysis by OTA indicates that if the two repositories required by the Act are operating at full scale by 2008 and 2012, respectively, spent fuel could be removed from all reactor sites within 10 to 15 years after the reactors are expected to cease operation. MRS or other backup isolation facilities, if operating by the same dates, would provide the same margin of safety.

Relations With States and Indian Tribes

State and Tribal Role in Siting Decisions

NWPA requires DOE to engage in an extensive process of consultation with States and affected Indian tribes throughout the repository site selection and development process. The Act gives the State or tribe the right to veto the President's selection of a repository site, a veto that can only be overridden by joint action of both Houses of Congress. Similar provisions apply to other waste management facilities addressed by the Act. Because of the distrust that had arisen between the Federal waste program and the States, legislated guarantees of clearly specified rights in the siting process were needed to provide a stable basis for intergovernmental relations during the implementation of the Act.

Impact Compensation

Waste management activities will produce many of the negative impacts associated with other industrial activities, such as the "boomtown" effects of large construction projects in small communities, as well as less familiar ones arising from the radioactive nature of the waste. NWPA requires DOE to make payments from the Nuclear Waste Fund (see below) to States, affected Indian tribes, and in some cases local governments, to compensate for the negative impacts of development and operation of waste management facilities. These arrangements should help assure those States and localities that they will not bear a disproportionate share of the burden of radioactive waste management. However, there will probably be positive impacts as well. For example, the first repository—which is likely to be the first such facility in the world—may become an international research center on high-level radioactive waste disposal. Such a center would produce long-term benefits for the community that might offset the more immediate but short-term adverse impacts of repository construction.

Institutional Measures

Waste Disposal Fee

DOE estimates that the total program outlays for high-level radioactive waste management through the year 2028 could range from as little as $16 billion to as much as $114 billion, depending on inflation and technical variations. A middle range, assuming 3 percent inflation, is from $35 billion to $64 billion.

To provide the assured source of funds to maintain steady progress over a period of decades, NWPA establishes a Nuclear Waste Fund financed by a mandatory fee on nuclear-generated electricity. The fee is initially set at 1 mill (0.1 cent) per kilowatt-hour. The rate must be reviewed annually by the Secretary of Energy and adjusted as needed to ensure that the full costs of the Federal waste disposal program are recovered. (Studies by DOE and the Congressional Budget Office conclude that some fee increase will likely be needed to cover inflation and possible increases in program costs.) This arrangement allows funding levels to be determined by the legislated goals, rather than having the achievable goals limited by the availability of funds, as occurred in the past. In return for this fee, DOE is required to sign contracts with utilities to dispose of waste after the first geologic repository is available. DOE will take title to the waste at the owner's site and transport it to the repository for disposal.

Single-Purpose Waste Management Office

NWPA establishes within DOE a single-purpose Office of Civilian Radioactive Waste Management, headed by a Presidential appointee and separate from the other nuclear activities of DOE. This step will help to insulate the program from the competition for manpower and policy-level attention that has adversely affected the program in the past. It could also help to provide the degree of central, integrated planning and management that is needed to meet long-term commitments on schedule. At the same time, the Act requires DOE to submit a study of alternative means of financing and managing the waste management program, including such options as establishing a private corporation.

Radioactive Waste Management Mission Plan

NWPA also requires DOE to submit to Congress a detailed Mission Plan for fulfilling the requirements of the Act. Such a Plan would provide a key tool for program management and for congressional oversight of DOE's waste management activities. **In OTA's view, development of a highly credible Mission Plan is the crucial next step in building confidence that the job of waste management will get done in a safe and timely manner.** The issues to be resolved in the Mission Plan are discussed below.

REMAINING ISSUES

Issues in the Mission Plan

According to NWPA, the Mission Plan is intended to provide "an informational basis sufficient to permit informed decisions to be made." To do this, the Mission Plan needs to identify the key strategic decisions and options involved in developing the proposed waste management system, and to provide information and analysis to support a choice among the options. The major strategic issues in the Mission Plan concern:

1. *the long-term waste management plan*—a plan for transferring spent fuel or high-level waste from the owners' storage facilities to Federal disposal facilities—involving a repository loading schedule, a plan for spent fuel storage after 1998, and a plan for providing long-term alternatives if major difficulties are encountered with geologic repositories; and
2. *the implementation program* for carrying out that plan, involving a repository siting program and a technology development program.

The choices among options for the repository schedule and the technology development and repository siting strategies represent key decisions in the Mission Plan. **Because the implications are so significant, the Mission Plan should include a comparative evaluation of alternative repository development and siting strategies, including those developed in the OTA Mission Plan.** This would enable Congress to evaluate the strategy selected by DOE in the light of a more detailed comparison of alternatives than OTA was able to perform. It would also allow DOE to explain and justify its choices, thereby increasing the credibility of the Mission Plan and the entire waste management program. The *Draft Mission Plan* published in 1984 does not explain the choices DOE has made, nor does it evaluate alternatives to those choices.

In OTA's view, development by DOE of an achievable, responsive Mission Plan is the crucial next step for stabilizing the waste management program and for establishing the necessary level of confidence and support. If the Mission Plan leaves some affected parties strongly dissatisfied with the way major questions are resolved, there will be a continued risk of future policy shifts like those that have characterized the program in the past, and the credibility of long-term Federal commitments will suffer. An acceptable Mission Plan might provide a key tool for program management and for congressional oversight of DOE's waste management activities, but dissatisfaction would probably result in strong opposition to giving the program greater managerial and financial independence than it already has. **In fact, it may not be possible to gain broad support for the creation of an independent waste management organization until a widely accepted Mission Plan is developed.**

While analyzing NWPA, OTA identified the basic elements of a Mission Plan that meets these requirements. This "OTA Mission Plan" is conservative in goals but aggressive in action, and OTA believes that it will be widely regarded as feasible and achievable. Its major elements are summarized below, in order to support OTA's conclusion that there is at least one workable approach to managing nuclear waste using the authority provided by NWPA. In general, it represents an expansion, rather than a redirection, of the approach DOE followed in the past and presented in the *Draft Mission Plan*. DOE can proceed with its ongoing repository development activities without precluding consideration of the strategic options suggested by OTA.

The following discussion highlights the key strategic choices to be made in implementing NWPA and identifies areas in which additional analysis by DOE would provide valuable information for congressional deliberations.

Repository Loading Schedule

Geologic repositories are the only facilities authorized and required by NWPA for DOE to use for fulfilling its legal responsibility for waste disposal. For this reason, the repository program is the heart of the OTA Mission Plan. The crucial decision concerning the repository loading schedule is the balance between the degree of *certainty* that the schedule can be met, and the promised *speed* of the schedule. Developing a geologic repository involves many first-of-a-kind technical and institutional steps. The faster the promised schedule, the less margin there is for delays or problems at any of these steps, and the less confident one can be that the schedule can be met.

DOE's *Draft Mission Plan* uses a repository schedule that can only be met if no significant delays are encountered. Initial loading at the first repository is scheduled to begin in 1998, the date NWPA requires, with full-scale operation expected by about 2001. DOE does not specify when loading might begin if there are serious problems or major delays. Questions about the credibility of the Federal waste management program in the past have stemmed in part from similarly optimistic schedules that have not been met. The credibility of DOE's Mission Plan would be enhanced if contractual commitments do not assume that everything will go right the first time.

OTA concludes that small-scale operation of the first repository probably can begin by the NWPA deadline of January 31, 1998, if a suitable site can be found from among those already under consideration at the time the Act was passed. The OTA Mission Plan therefore uses this date as a management target for *initial* operation, to maintain pressure for steady progress towards a licensed repository site. It also includes additional measures, discussed below, to increase confidence in that target.

Although NWPA establishes a deadline for *initial* disposal in a repository, however, it does not specify how quickly the *full-scale* transfer of waste from utilities to the repository is to occur. The Mission Plan needs to do so. This *repository loading schedule* then becomes the basis for contractual commitments, in order to give utilities a basis for planning interim storage. The OTA Mission Plan uses a conservative repository loading schedule based on two repositories in full-scale operation by 2008 and 2012, dates that can be met despite major delays or problems. **If the contingencies allowed for in this schedule do not arise, full-scale operation could begin years earlier—perhaps as early as provided in DOE's proposed schedule.**

Repository Siting Strategy

The major issue in siting and developing the geologic repositories is the balance between: 1) the desired degree of certainty that a repository will be available without major delays; and 2) the initial costs of the program, both financial and political. **It is impossible to both maximize the certainty of the repository schedule and minimize the initial costs at the same time.** The implementation program in the OTA Mission Plan emphasizes certainty and places great weight on the importance of minimizing the risk of major programmatic delays. **This approach increases the level of confidence in the repository schedule and perhaps reduces overall costs, but it may also increase the initial costs.** The repository siting strategy is crucial to this approach.

DOE's *Draft Mission Plan* provides for considering only the number of sites required by NWPA at key stages of the siting process. Specifically, three sites would be characterized for each repository, and one site would be submitted to NRC for construction authorization. This is unchanged from the program that was in place before NWPA made a major Federal commitment in law to operating a repository on a firm date. **OTA's analysis indicates that expanding that program to include one additional site at those key stages is both necessary and sufficient to substantially increase the level of confidence that the new commitment made by NWPA will be met.**

The siting process is the principal source of uncertainty in the repository program. Because there is no previous experience with most of the technical and institutional problems involved, there is no consensus on how much time will be required to complete each stage or the likelihood that a given site will be rejected at any stage. The best way to increase confidence that major delays will be avoided, in the face of these uncertainties, is to carry more than the required number of sites through each stage. This ensures that backups are available without delay if needed, so that extended delays or failures at any one site will not hold up the entire process.

The OTA Mission Plan includes a siting program that exceeds the requirements of NWPA in two principal areas: characterizing four sites for each repository, instead of three; and recommending two sites for each construction authorization, rather than one. Using an expanded siting strategy significantly increases the likelihood of meeting the 1998 deadline for *initial* operation. This strategy is the principal assumption underlying OTA's conclusion that the first repository could be in *full-scale* operation by 2008 despite difficulties with some sites.

NWPA requires that characterization be *completed* at three sites before one can be recommended. Beginning the characterization stage with four sites allows a site to be recommended as soon as the fastest three sites are finished; if only three sites are characterized, the schedule depends on progress at the slowest site. Similarly, submitting two sites to NRC for licensing, rather than one, means that construction could proceed as soon as either site receives authorization.

It is also possible that NWPA may be interpreted as requiring three sites that, after characterization, appear *suitable* for licensing, before one can be *recommended* for licensing. Characterizing four sites provides insurance against the delay that could result from a lawsuit to resolve this question. This approach also increases the credibility of the State veto provisions of NWPA by increasing the likelihood that Congress will have a readily available alternative, if and when it has to decide whether to overrule a State's objection to the final site. (The Act requires DOE to recommend a second site within one year in the event that Congress upholds a State objection. This can only be done if a second *suitable* site is available from among the first set of sites that are characterized.)

The OTA Mission Plan calls for only one additional site at each stage for reasons of cost effectiveness. Again, the Act requires characterization of three sites before one can be recommended; even if there is only a 20 percent risk of delay or rejection at an individual site during characterization, there would be nearly a 50 percent risk of delay in having all three sites ready for the next stage. Adding a fourth site during characterization reduces that overall risk to 18 percent, a significant improvement, but adding a fifth site provides a smaller improvement, to 6 percent. Similarly, if there is a 20 percent risk that a single recommended site will be rejected for construction authorization, recommending two sites reduces the risk to 4 percent, while recommending a third reduces the risk only to 1 percent.

OTA's analysis suggests that the additional costs of an expanded implementation program would produce offsetting benefits that are not readily quantifiable. First, it increases the credibility of the process by allaying concerns that key decisions might be compromised by lack of suitable alternatives. Second, it substantially reduces the risk that the credibility of the Federal program might be damaged by major delays in the repository program. Because of its troubled history, any major programmatic failure—real or perceived—could have grave consequences for both the waste management program and the continued use of nuclear power. **The greater initial costs of the OTA Mission Plan may thus be regarded as insurance for a program that cannot afford any major failures or delays.** NWPA provides authority for such an approach, as well as a source of funding that can be adjusted to cover its costs. DOE's *Draft Mission Plan*, on the other hand, proposes measures to speed up the repository development process, at significant cost, but these measures do not provide the insurance against major delays offered by consideration of additional sites.

Technology Development Strategy

The OTA Mission Plan calls for development of the first repository to be accomplished in two stages: 1) a *demonstration phase*, to show that a licensable disposal technology exists; and 2) an *operational phase*, to dispose of radioactive waste on a large scale.

The demonstration phase would use a *conservative system design* that emphasizes certainty in meeting regulatory requirements. A small amount of waste (e.g., several hundred tonnes) would be placed in conservatively designed packages during the packaging and handling RD&D program required by NWPA. Permission would be requested from NRC to emplace this material in the repository as soon as possible following construction authorization—*before* the repository's packaging facilities are built instead of after, as indicated in DOE's *Draft Mission Plan*. (If DOE builds an unlicensed test and evaluation facility at the repository site, as authorized by NWPA, the demonstration phase could be simply a licensed extension of the activities conducted in that facility.) Using a conservative system design, involving low repository temperatures and a waste package whose lifetime exceeds NRC's requirements, would reduce the number of technical issues to be resolved before initial licensed emplacement is allowed. This approach would allow early demonstration of both the technology and the institutional steps required for licensed disposal. It should thereby maximize the likelihood of meeting NWPA's 1998 target for initial repository operation.

The operational phase would use an *optimized, integrated system design,* aimed at reducing the overall risks, costs, and impacts of waste management operations, from discharge of spent fuel from a reactor to final disposal in a repository. For example, recent analysis suggests that significant operational benefits, including substantially reduced costs, might result from using a universal container—a package into which spent fuel would be placed at the reactor and in which it would remain for all subsequent waste management steps, unless it were removed for reprocessing. **Because this container and other relatively new technologies will require additional RD&D, the schedule for the operational phase would be determined by the time required to develop and license an optimized system design.**

This two-stage approach may increase initial costs compared to DOE's *Draft Mission Plan,* because it requires development of two disposal system designs and may defer full-scale operation for a few years. At the same time, it may reduce total costs in the long run because: 1) it removes the construction of the repository's packaging facility from the critical path for initial disposal; and 2) it thereby avoids the risk that attempting to meet the 1998 deadline using those facilities, as proposed by DOE, might preclude the use of a significantly improved system design at the first repository. In addition, it increases confidence in the schedule for full-scale operation, because the conservative system design could still be used if problems were encountered with the optimized design.

Issues in the MRS Proposal

The second document to be submitted to the 99th Congress is the MRS proposal, containing both designs for such facilities and an analysis of the need for them and their feasibility. As noted earlier, it now appears that MRS facilities will not be necessary for safe waste management unless major unexpected difficulties with geologic disposal are encountered. The OTA Mission Plan provides for a delayed decision to construct MRS facilities (or alternative disposal facilities) as a long-term backup to repositories, in the event that major unanticipated difficulties are encountered with geologic disposal.

The major storage issue to be considered in the Mission Plan and the MRS proposal is whether to authorize earlier construction of an MRS facility. To facilitate congressional consideration of MRS options, both the Mission Plan and the MRS proposal should evaluate at least three alternatives:

1. **Early siting, licensing, and construction of an MRS facility.** This could be done for several reasons: to provide a cushion against delays in the repository program; to play an operational role in an integrated waste management system; or to allow more time to be taken in finding repository sites. This option, which is implicit in DOE's *Draft Mission Plan,* would require congressional authorization in the very near future. It involves a major additional commitment of manpower and resources over the next decade, which might raise concerns that this effort would adversely affect the repository siting process.
2. **Federal at-reactor storage beginning in 1998.** Under this option, the Nuclear Waste Fund would pay the costs of additional storage beyond the contractual delivery date. This avoids the costs of siting and licensing a large new facility, and it would spread the costs of delays in the repository program among all utilities paying the waste disposal fee. This option might be accomplished through rulemaking, by modifying contracts with utilities; if

so, no congressional action would be required. This approach is compatible with a later decision to construct a centralized storage facility, if needed, but it would also allow planning for at-reactor storage as an integral part of the waste management system. If it were taken by DOE soon, it would separate the equity issue of *who* should be responsible for post-1998 interim storage from the technical question of *where* that storage can best be provided.

3. **Deferral of the decision on a centralized MRS facility until at least 1990, when DOE expects to recommend the first geologic repository site to Congress.** This allows enough time to: 1) evaluate the demonstrations of at-reactor dry storage technologies required by NWPA; 2) complete the analysis of an optimized integrated waste management system design that has recently been initiated by DOE; and 3) determine from the results of site characterization whether the repository program can expect significant delays. It also avoids the risk that an early effort to site a large-scale storage facility would delay the repository program. If a decision were made in 1990 to construct an MRS facility, it could begin operation by 2001, DOE's current target date for operation of the full-scale loading facilities for the first repository. Even if the decision were made as late as 1998, it would still allow alternative facilities to be available quickly enough to remove spent fuel from reactor sites within 15 years after decommissioning. This option would require no congressional action at this time.

Institutional Issues

Finally, DOE will submit to the 99th Congress a report on alternative institutional mechanisms for financing and managing the commercial high-level radioactive waste program. The central component of NWPA is its commitment to developing a complex technological system, faced with technical and institutional uncertainties, on a firm schedule extending over a period of decades. **The confidence in and credibility of this commitment could be enhanced by establishing an independent waste management agency with more funding and management flexibility than is usual with a typical Federal program.** Creating such an agency may be the best way to ensure that implementation of NWPA would not be adversely affected by other fiscal and political priorities of the Federal Government. In addition, separating this agency from Federal activities that promote energy production could enhance the credibility of the program for those who see a conflict of interest between such activities and the safe planning and development of a waste management system.

The degree of financial independence of the waste management organization will be of particular importance. NWPA insulates the revenues produced by the waste management fee by establishing a separate Nuclear Waste Fund in the Treasury, limited to carrying out the purposes of the Act. Although the budget for the program is to be submitted and expenditure levels authorized on a triennial basis, the use of the Fund is subject to annual appropriations. Since annual budget control is not entirely consistent with a commitment to steady progress on a long-term schedule, any future deliberations on establishing an independent waste management agency will have to consider ways of providing such an agency with greater budgetary independence. Without such independence, there will be a risk that considerations of the annual Federal budget (e.g., pressures to limit the temporary borrowing from the Treasury that may be needed to balance the flow of revenues and expenditures in the Waste Fund) could lead to deferral or elimination of planned expenditures. This could in turn jeopardize steady progress on a program whose schedule has been fixed by contracts with utilities.

Achieving an acceptable balance between independence and accountability will be one of the central challenges in designing such a waste management authority. The more independent the institution and its funding are, the surer the guarantee that nuclear waste management activities will be carried out on schedule. But such an institution raises a crucial and difficult question: how to ensure the congressional oversight and public accountability that a democratic society demands. There may be considerable reluctance to establish a single-purpose agency with even greater independence than the current institutional structure, for fear that it might be less responsive to the concerns of Congress, the administration, and the public.

The Mission Plan could serve as the principal mechanism for balancing the need for adequate congressional oversight with the need for increased flexibility of operation. Using the Mission Plan for this purpose could be easier and more effective if there were a process by which Congress could approve it. Since this is not now required by NWPA, consideration of mechanisms for such approval might be included in any congressional deliberations on establishment of an independent waste management agency.

If there were a mechanism for congressional approval of a Mission Plan, the function of the waste management agency would be that of carrying out a specific program, with specific goals that Congress has formally approved, and not that of developing broad waste management policy. This might give Congress sufficient ongoing control to warrant relaxation of normal annual budgetary controls, thus increasing confidence that the waste management program will have adequate funds available when needed regardless of other Federal budget priorities. Once congressional approval is obtained, the agency could be authorized to make expenditures from the Nuclear Waste Fund, as provided for in a multiyear budget contained in the Mission Plan, without annual authorizations or appropriations. To ensure continued congressional control, revision and reapproval of the Mission Plan could be required at regular intervals (e.g., every 4 to 6 years).

The added independence that could be gained under this approach might give the waste management agency the incentive to develop and carry out a highly defensible and widely supported Mission Plan. A regular process of review and reapproval could increase public understanding of and support for waste management activities. It would also allow Congress to reconfirm its commitment, made in NWPA, that there would be steady progress toward the permanent disposal of high-level radioactive waste.

Chapter 2

Radioactive Waste: Its Nature and Management

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Chapter 2

Radioactive Waste: Its Nature and Management

Various forms of radioactive waste are produced during the preparation, use, and management of reactor fuel for the commercial production of electricity and for defense-related nuclear activities. Radioactive waste is also produced in various industrial and institutional activities, including medical research and treatment. The focus of this assessment is the management of the highly radioactive waste produced during the generation of commercial nuclear power.

In a nuclear powerplant, heat released when atomic nuclei in reactor fuel are made to split (fission) is used to produce steam that powers an electricity-producing generator. This process creates not only the heat needed for generating electricity, but also radioactive byproducts that are present in the "spent" (used) fuel discharged from the reactor. The term *high-level radioactive waste* is used in this report to refer to either the high-level waste material produced if the unused radioactive byproducts are separated from the spent fuel for disposal or the spent fuel itself if it is discarded directly as waste. This chapter will describe the nature of radioactive waste; its sources, amounts, and hazards; and the technical and institutional aspects of its management.

NATURE OF RADIOACTIVE WASTE

Nuclear Reactions

Radioactivity

Some atoms, known as radioisotopes, are unstable (radioactive) and undergo a spontaneous decay process, emitting radiation until they reach a stable form. Called *decay,* this stabilizing process takes, depending on the type of atom, from a fraction of a second to billions of years. The rate of radioactive decay is measured in half-lives, the time it takes for half the atoms in a sample to decay to another form. After 1 half-life, half the atoms in a sample are unchanged; after 2 half-lives, one-fourth of the original amount remains unchanged. Thus, after several half-lives only a small fraction of the sample's original atoms remain unchanged; yet the sample may still be quite radioactive—either because some atoms have not decayed or because some atoms have decayed to other radioisotopes.

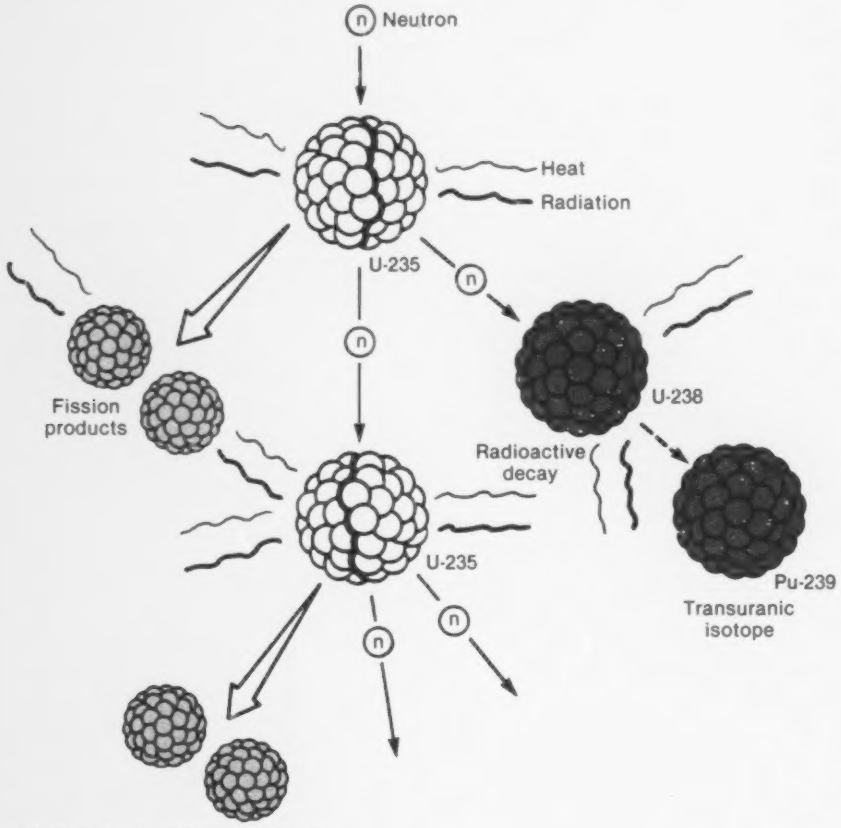
The intensity of radioactivity in a sample is determined by the number of emissions, or disintegrations, per second and usually is measured in curies (1 curie = 37 billion radioactive disintegrations per second). From this standard, three common measurements are derived: the nanocurie (1 billionth of a curie), the microcurie (1 millionth of a curie), and the megacurie (1 million curies). Elements with shorter half-lives—like thorium-234 at 24.1 days—are more radioactive than those with longer half-lives—like uranium-238 (U^{238}) at 4.5 billion years—because the shorter the half-life, the more atoms in a sample of the element decay and emit radiation each second.

Fission

Some radioisotopes are fissile—i.e., they can split when neutrons are added to their nuclei or, in some circumstances, spontaneously. Only one fissile element, uranium-235 (U^{235}), exists in nature. Others are produced artificially when "fertile" atoms such as U^{258} absorb neutrons and subsequently decay to fissile isotopes, like plutonium-239 (Pu^{239}) (see fig. 2-1).

During fission, the nucleus splits into two smaller nuclei called fission products, releasing neutrons, radiation, and heat in the process. The released

Figure 2-1.—Fission Process



SOURCE: Office of Technology Assessment.

neutrons can cause nearby atoms to split, and, given enough fissionable material, an ongoing chain reaction can begin. Such a chain reaction generates heat, primarily from the fission process itself and secondarily from the subsequent decay of the radioactive fission products. Uncontrolled, a nuclear chain reaction could end in an atomic explosion. In a nuclear reactor, however, the fissile atoms (U^{235}) are diluted with many non-fissile atoms (U^{238}) and other atoms that absorb neutrons so that the chain reaction is maintained but cannot produce an explosion.

Produced in great quantities in a reactor are: 1) transuranic (TRU) isotopes—atoms that absorb enough neutrons to become heavier than uranium atoms, and 2) fission products—isotopes lighter than uranium atoms that are formed by the fission of an atom. Generally, fission products are more radioactive and have short half-lives, from seconds to decades. TRU isotopes can have half-lives as long as millions of years.

Effects of Radiation

Highly energetic radiation can penetrate human tissue and other matter, triggering molecular and chemical changes that can result in damage or death to cells, tissue, or even the entire organism. The extent of the damage depends on the type of radiation, the length of exposure, the distance from the radiation source, and the susceptibility of the exposed cells. The principal concern about radioactive waste is that it might be released into the environment and be taken into the body through drinking water or food supplies, thus placing a source of radiation very close to vulnerable tissues.

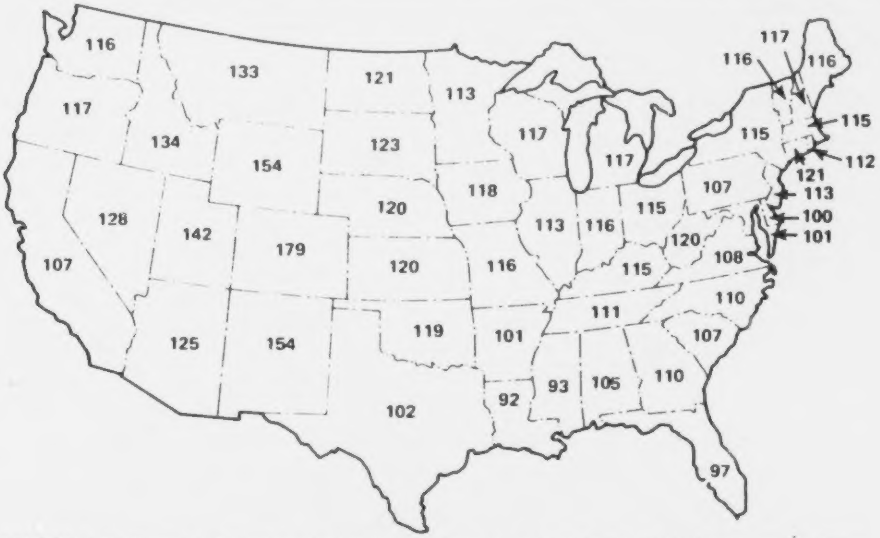
Radiation exposure is measured in rems, a unit that indicates the amount of radiation received and the biological implications of the exposure. In a year's time, the average person in the United States is exposed to approximately 160 millirems (thousandths of a rem) of radiation, two-thirds of which comes from natural background sources such as mineral ores, cosmic radiation from outer space, and the radioactive carbon and potassium found in most living things. Natural background radiation from outer space increases with land elevation and is about twice as high for a person living in Denver, Colo., as for a person living at sea level (see fig. 2-2). Slightly less than one-third of this annual exposure comes from medical irradiation (X-rays).

An acute radiation dose—50 rems or more over a 24-hour period—results in radiation sickness within 1 hour to several weeks. The chance of death is nearly 100 percent from a dose above 1,000 rems, 90 to 100 percent from 600 to 1,000 rems, and 50 percent from 400 rems. With a dose of 200 rems or less, survival is almost certain. Other consequences range from gastrointestinal and circulatory system disorders to long-term effects like cancer, birth abnormalities, genetic defects, and poor general health. Long-term effects also result from chronic exposure to low-level radiation. In radioactive waste disposal, the concern centers on the possibility of such chronic low-level exposures caused by escaped waste, rather than acute doses.

The Nuclear Fuel Cycle

Several kinds of radioactive waste are generated during all stages of the nuclear fuel cycle—from the preparation of reactor fuel (front-end of the cycle), through the operation of the reactor, to the storage and possible reprocessing of spent reactor fuel (back-end of the cycle). The following activities comprise the nuclear fuel cycle for uranium both as originally envisioned and as now in use in the 74 operating commercial nuclear powerplants in the United States.

Figure 2-2.—Natural Background Radiation Varies From State to State (millirem per year)



SOURCE: A. W. Klement, Jr., *Estimates of Ionizing Radiation Doses in the United States, 1960-2000*, Environmental Protection Agency Publication No. ORP/CDS 72-1, 1972.

Box A.—Forms of Radioactive Waste

Spent fuel.—Irradiated fuel discharged from a nuclear reactor. Contains fission products, unused uranium and plutonium, and various transuranic (TRU) elements.

High-level waste (HLW).—Highly radioactive material resulting from chemical processing of spent fuel to recover usable uranium and plutonium. Contains fission products, traces of uranium and plutonium, and other TRU elements.

Transuranic (TRU) waste.—Materials contaminated with enough TRU elements to require the same sort of long-term isolation as high-level radioactive waste.

Mill tailings.—Slightly radioactive materials left over from extraction of uranium from ore.

Low-level waste (LLW).—All radioactive wastes not classified as high-level radioactive waste, TRU waste, mill tailings, or byproduct material as defined in Public Law 96-573. While most are relatively short-lived and have low radioactivity, some may present a significant radiation hazard.

Front End of the Fuel Cycle: Preparation of Reactor Fuel

MINING

Uranium ore, the raw material of reactor fuel, is extracted from surface and underground mines, producing low-level radioactive dust and releasing radioactive gas.

MILLING

At mills the uranium ore is crushed and ground, then chemically treated to extract uranium oxides and produce yellowcake (U_3O_8). The process generates low-level airborne wastes and a large volume of slightly radioactive mill tailings.

CONVERSION AND ENRICHMENT

Yellowcake is converted to uranium hexafluoride gas (UF_6), leaving low-level waste solids. At enrichment facilities the concentration of U^{235} in the gas is increased from the 0.7 percent found naturally in uranium ore to the 3 to 4 percent needed for fuel for the reactors in use in the United States. In the process, low-level airborne and liquid waste are produced.

FUEL FABRICATION

The enriched UF_6 gas is then converted to solid uranium dioxide (UO_2), shaped into pencil eraser-size pellets, and loaded into 12-ft long metal fuel rods. The rods are then sealed, arrayed in fuel assemblies of 50 to 300 rods, and transported to reactors. Low-level gas, liquid, and solid radioactive waste remain.

Reactor Operation

The light-water reactor (LWR) is the principal reactor type in commercial use in the United States.[1] In the LWR, the fuel assemblies are immersed collectively in a coolant (water), where they form the reactor core. The control rods interspersed among the fuel rods control the number of nuclear reactions in the reactor fuel. Heat from fission and, to a lesser extent, from the decay of fission products is used to heat water to steam. In one type of LWR, the boiling-water reactor (BWR), the steam is produced directly from the cooling water surrounding the reactor core. In the other type, the pressurized-water reactor (PWR), the cooling water is pressurized to prevent boiling and is used instead to transmit heat from the core to boil water in a separate steam generator. In both types the steam causes a turbine to rotate, generating the electric power transmitted to consumers. A typical nuclear powerplant produces about 1 million kilowatts (kW), or 1 gigawatt (GW_e), of electricity.

After about 3 years, the buildup of fission products and TRU elements in a fuel assembly impedes the efficiency of the chain reaction. When the concentration of U^{235} in the fuel is less than 1 percent, the assembly, considered "spent" fuel, is removed and replaced with fresh fuel. A typical 1-GW_e PWR discharges about 60 assemblies, or a total of about 27 metric tons (tonnes)[2] of spent fuel, each year, while a 1-GW_e BWR discharges about 175 assemblies, or 31 tonnes, annually.[3] Table 2-1 shows the characteristics of BWR and PWR fuel assemblies before and after irradiation in a reactor.

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[1] Seventy-three of the seventy-four commercial powerplants are LWRs. The one high-temperature gas reactor at Fort St. Vrain, Colo., operates like an LWR but uses helium gas for its coolant. Another type of reactor under consideration for future use is the breeder reactor, designed to produce more fissile material than it uses by converting nonfissile U^{238} in the fuel into plutonium, which would be extracted through reprocessing and recycled as new fuel.

Because of the decay of the fission products and TRU elements, spent fuel is extremely hot and radioactive when it is initially discharged from the reactor. For this reason it is stored in water basins to provide the cooling and radiation shielding that it requires. For example, freshly discharged spent fuel from a PWR generates up to about 221 megacuries of radioactivity and 2.2 megawatts (MW) of thermal heat per tonne.[4] BWR fuel is slightly less hot and radioactive, since it generally has a lower "burnup"—a measure of the amount of the fissile material in the fuel that has been used before discharge, and thus of the amount of radioactive waste products it contains.

Table 2-1.—Physical Characteristics of LWR Fuel Assemblies

	BWR	PWR
Overall assembly length (m)	4.470	4.059
Cross section (cm)	13.9 × 13.9	21.4 × 21.4
Fuel pin array	8 × 8	17 × 17
Fuel pins/assembly	63	264
Nominal volume/assembly (m^3)	0.0864	0.186
Assembly total weight (kg)	275.7	657.9
Uranium/assembly (kg)		
Initial	183.3	461.4
Discharge	176.5	441.2
Enrichment (wt% U^{235})		
Initial	2.75	3.20
Discharge	0.69	0.84
Plutonium/assembly at discharge (kg)	1.54	4.18
Other TRU elements/assembly at discharge (kg)	0.10	0.43
Fission products/assembly at discharge (kg)	5.2	15.7
Average discharge burnup (MW-d/tonne initial uranium)	27,500	33,000
Average thermal power (kW/assembly)		
Discharge	278	1,017
1 year after discharge	1.3	4.7
10 years after discharge	0.2	0.5
Average radioactivity (megacuries/assembly)		
Discharge	28.3	102.0
1 year after discharge	0.35	1.16
10 years after discharge	0.06	0.18

SOURCE: Derived from data presented in A. G. Croff and C. W. Alexander, *Decay Characteristics of Once-Through LWR and LMFBR Spent Fuels, High-Level Wastes, and Fuel Assembly Structural Material Wastes*, ORNL/TM-7431 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, 1980).

The heat output and radioactivity of spent fuel decay rapidly in the first year after discharge, by factors of 216 and 88, respectively, for PWR fuel. The approximately 10 kW of heat emitted per tonne after one year equates to that of one-hundred 100-watt light bulbs. The heat and radioactivity decay less rapidly after the first year, by additional factors of 8 and 6, respectively, by the end of 10 years after discharge.

Backend of the Fuel Cycle: Spent Fuel Management and Waste Isolation

At present, many of the activities envisioned to treat and manage commercial spent fuel exist in theory, based on extensive experience with defense spent fuel, but not in practice. Thus, deciding what to do with commercial spent fuel and the waste products it contains is often referred to as "closing the back end of the nuclear fuel cycle." The following section provides an overview of the existing and envisioned activities of the back end of the fuel cycle.

REPROCESSING AND RECYCLE

Spent fuel contains much material of no discernible value, as well as uranium and plutonium, over 99 percent of which can be recovered through reprocessing and then recycled for reactor fuel. In the reprocessing operation, spent fuel rods are chopped into pieces and dissolved. From the solution all but 0.5 percent of the uranium and plutonium is extracted. If the recovered uranium were recycled, it would be converted to uranium hexafluoride (UF_6) gas for reuse in producing fresh nuclear fuel. If the recovered plutonium were recycled, it would be converted to plutonium oxide (PuO_2) and combined with uranium to make mixed oxide (MOX) fuel.

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[2] Note that only the mass of the initial uranium is considered in the measurement of fuel amounts and not the mass of the rest of the assembly. While this report will use the term "tonnes" for simplicity, other terms in common use are MTU (metric tons of uranium), MTHM (metric tons of heavy metal), and MTIHM (metric tons of initial heavy metal). A metric ton, or tonne, is equivalent to 1,000 kilograms, or about 2,205 pounds.

[3] National Research Council, Waste Isolation Systems Panel, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, D.C.: National Academy Press, 1983), pp. 28-29. See chapter note 1 for further discussion of the amounts of spent fuel produced by the generation of 1 GW-year of electricity.

[4] A. G. Croff and C. W. Alexander, *Decay Characteristics of Once-Through LWR and LMFBR Spent Fuels, High-Level Wastes, and Fuel-Assembly Structural Material Wastes*, ORNL/TM-7431 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, November 1980).

The leftover solution from reprocessing, highly radioactive at 10,000 curies per gallon, contains primarily fission products and is defined as high-level waste. It must, by regulation, be solidified before disposal. Any recovered uranium or plutonium that is not recycled must also be disposed of. Both reprocessing and MOX fuel fabrication generate substantial quantities of TRU wastes—materials contaminated with enough long-lived TRU elements to require long-term isolation like high-level waste.

Defense spent fuel—from reactors designed to produce plutonium for weapons and from the powerplants of nuclear naval vessels—routinely is reprocessed to recover plutonium and unused enriched uranium. The nuclear fuel cycle was originally envisioned to include such reprocessing for all commercial spent fuel. However, for economic and political reasons discussed in chapters 3 and 4, no commercial spent fuel is now being reprocessed in the United States. Of the three commercial reprocessing plants originally planned, only the facility at West Valley, N.Y., actually operated (from 1966 to 1972). It closed for modifications and never reopened. The facility at Morris, Ill., had design problems and never opened, and the facility at Barnwell, S.C., has never been completed. Without commercial reprocessing there can be no commercial recycling of uranium or plutonium.

WASTE MANAGEMENT

Nearly all the highly radioactive byproducts produced thus far by commercial nuclear power generation in the United States are contained in the spent fuel that has been discharged by operating reactors. The original expectation that all spent fuel would be reprocessed to recover usable uranium and plutonium, and that the radioactive byproducts would be separated as high-level waste, has not been realized. It now appears possible that at least some spent fuel would be treated as waste and discarded directly without reprocessing, which is often referred to as a "once-through" fuel cycle. Thus, the term *high-level radioactive waste* is used in this report to refer to either the high-level waste from reprocessing or the spent fuel itself, if discarded as waste. Because of the uncertain future of reprocessing, high-level radioactive waste management at present can be seen as including: 1) management of spent fuel until a decision is made about whether to reprocess it, and 2) final isolation of the fission products and unused TRU elements that are now in the spent fuel and that may or may not be separated later.

Box B.—Key Waste Management Definitions

Isolation.—The placement of radioactive materials so that contact between the material and humans (or the environment) is highly unlikely for a specified period of time.

Final isolation.—Placement of radioactive material in a final resting place, so that removal to another site is neither necessary nor expected for as long as required by safety regulations. Synonymous with permanent isolation and terminal isolation.

Disposal.—Operations designed to provide final isolation—with no provision for easy recovery of the emplaced waste—by relying on a combination of manmade and natural barriers, rather than on continuous human control and maintenance, to ensure the isolation of the waste. While disposal sites and facilities must be designed to provide disposal, as just defined, they may also may be used for storage or other activities prior to disposal.

Storage.—Operations, designed to provide isolation and easy recovery of radioactive materials, that rely on continuous human monitoring, maintenance, and protection from human intrusion for a specified period of time.

Interim storage.—Temporary storage with the intention and expectation that radioactive materials will be removed for subsequent treatment, transportation, or isolation. Limited interim storage is defined by the Nuclear Regulatory Commission (NRC) as 20 years, renewable at the option of NRC. Extended interim storage would be such storage for a very long (30+ years) and relatively open-ended, undefined period.

Permanent storage.—Storage used as a means of providing final isolation, with no intention of ever retrieving the waste.

The high-level radioactive waste management system is a network of facilities for storing spent fuel and any high-level waste from reprocessing, facilities for final isolation of whichever material is ultimately discarded, and transportation links connecting those facilities with one another and with any reprocessing and recycling activities that ultimately occur. Each of these activities will be described briefly here and discussed at greater length in chapter 3.

Interim Storage.—When the reactors that now are operating or under construction were designed, it was assumed that spent fuel discharged from the reactor would first be stored in water-filled storage basins at the reactor for about 6 months to dissipate the thermal heat and allow the decay of some of the short-lived fission products. It was expected that the spent fuel then would be reprocessed and the resultant high-level liquid waste solidified and shipped to a Federal repository for final isolation. Since no commercial reprocessing is being done, and no final waste repository exists that could allow spent fuel to be discarded directly, practically all spent fuel remains in storage basins at reactor sites. Modifications are being made where possible to increase the amount of spent fuel that can be stored in these basins, which originally were designed with a capacity for only 3 to 5 annual discharges of spent fuel. Transshipment (shipping spent fuel from one reactor site for storage in a basin at another site) and new storage technologies now under development promise additional relief (see ch. 3).

Because of the delays that have already occurred in the availability of both reprocessing and final repositories, it appears likely that most (more than 90 percent) of the spent fuel generated in this century will still be in temporary storage facilities at the end of the century—even if reprocessing or direct final isolation of spent fuel begins in the 1990's.[5] Thus, for the next several decades, waste management will consist primarily of interim spent fuel storage. Any reprocessing that occurs would simply convert some of the stored spent fuel into separated uranium and plutonium and waste of various types, all of which would require interim storage until final isolation of the waste and recycling (or perhaps direct final isolation) of the plutonium and uranium.

Final Isolation.—Final isolation, the last step in radioactive waste management, is intended to limit or prevent the release of highly radioactive byproducts of nuclear fission into the environment for the thousands of years it takes for these byproducts to decay to low levels. There is no licensed final isolation facility for high-level radioactive waste in the world.

There are two conceptually distinct technological approaches to waste isolation that could be used for final isolation: *storage* and *disposal*. Briefly, disposal is isolation that relies primarily on natural (environmental) and manmade barriers, does not permit easy human access to the waste after its final emplacement, and does not require continued human control and maintenance. Storage is isolation that permits easy access to the waste after emplacement and requires continued human control and maintenance to guarantee isolation. Thus, disposal is always designed to provide final isolation, while storage may be intended for either interim or final isolation.[6]

Although some have viewed long-term storage as a viable final measure for managing high-level radioactive waste,[7] Federal Government policy since the 1950's has been directed primarily toward the development of disposal facilities for final isolation. However, storage will of necessity be the only form of waste management until the capacity for disposal is available and may continue to be a major part thereafter—either because it is desirable to defer disposal even after facilities are available (e.g., to maintain easy access to spent fuel for possible reprocessing) or simply because an extended period would be required to eliminate the backlogs of waste built up in storage by the time disposal operations begin.

In the United States, Government efforts are focused on the development of mined, geologic repositories for disposal, although other disposal alternatives, such as emplacement in the seabed, have been and probably will continue to be considered. The Nuclear Waste Policy Act of 1982 (NWPA) commits the Federal Government to begin operation of a geologic repository by the beginning of 1998. Until the mid-1990's, the activities associated with disposal will involve locating and evaluating suitable repository sites and developing disposal technology (see ch. 3).

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[5] U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, September 1984, fig. C.2, p. 284, and fig. C.3, p. 285.

[6] Much of the debate about radioactive waste management has been clouded by blurred and shifting distinctions between storage and disposal. In particular, storage is often defined as emplacement with the intent to recover the material, while disposal is defined as emplacement with no intent to recover, a distinction which is based on a subjective criterion—the intention of the person emplacing the waste—that cannot be directly observed from inspection of the facility receiving the waste. In contrast, the definitions used in this report are based on the observable design characteristics of the system under consideration.

[7] *See app. A, p. 206.*

Transportation.—Linking the stages of the nuclear fuel cycle are transportation activities that also generate wastes, primarily from the contamination of transport containers by the transported materials. Because most commercial spent fuel is now stored at reactor sites, very little transportation of commercial spent fuel occurs in this country at this time, although some transshipment does take place.

Amounts of Radioactive Waste

High-Level Waste From Reprocessing

The principal source of high-level waste at present is the reprocessing of spent fuel from defense nuclear activities. Such waste is stored as liquid, salt cake, and sludge in near-surface tanks or as calcined solids in underground bins at Federal installations at the Hanford Reservation (Washington), the Savannah River Plant (South Carolina), and the Idaho National Engineering Laboratory. A small amount of high-level waste, from reprocessing about 234 tonnes of commercial spent fuel, is stored at the Nuclear Fuel Services facility in West Valley, N.Y. Table 2-2 shows the existing and projected amounts of high-level radioactive waste, in terms of volume, radioactivity, and thermal power (the rate of heat output). Note that if reprocessing of spent fuel from commercial power reactors is undertaken, it could rapidly become the dominant source of high-level waste.

Spent Fuel

By the end of 1983, about 10,000 tonnes of spent fuel was in storage in water basins at nuclear power reactors in the United States. Commercial spent fuel was being generated at a rate of about 1,400 tonnes/yr in 1983, and the Department of Energy (DOE) estimates the rate will reach about 2,300 tonnes/yr by 2000. This increase would result in a total of about 21,000 tonnes by the end of 1990 and 43,000 tonnes by the end of 2000.[8] The currently operating reactors can be expected to produce about 55,000 tonnes of spent fuel, or about 196,000 fuel assemblies, over their operating lifetimes.[9]

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[8] U.S. Department of Energy, op. cit.

[9] Projections supplied by the U.S. Department of Energy. See app. F.

Table 2-2.—Current and Projected Inventories of Defense and Commercial High-Level Radioactive Waste

	End of calendar year 1983			End of calendar year 2000		
Material	Volume[a] (cubic meters)	Radioactivity (megacuries)	Thermal power (kilowatts)	Volume[a] (cubic meters)	Radioactivity (megacuries)	Thermal power (kilowatts)
High-level waste:						
Defense:						
Savannah River	111,000	776	2,280	83,000	699	2,040
Idaho	10,000	65	190	14,000	241	726
Hanford	203,000	474	1,380	217,000	430	1,256
Defense total	324,000	1,315	3,850	314,000	1,370	4,022
Commercial:						
West Valley	2,000	35	104	—	23	68
Future[b]	0	0	0	300	324	1,106
Spent fuel:						
Cumulative	4,600 (10,000 tonnes)	12,900	48,000	19,400 (42.800 tonnes)	35,700	131,000
Annual	620 (1,400 tonnes)	7,400	29,400	1,050 (2,320 tonnes)	13,700	55,300

[a] Spent fuel volumes calculated using a nominal volume of 0.0864 m^3 for a BWR assembly and 0.186 m^3 for a PWR assembly. (DOE/NE-0017/2, table 1.9, p. 32.)

[b] Assumes a first reprocessing plant starts operation in 1995 at 500 tonne/yr through 2004.

SOURCE: U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Washington, D.C., 1984.

The total volume of existing and projected commercial spent fuel discharges is shown in table 2-2. Because most of the high-level defense waste is relatively dilute, and has not been concentrated and solidified, the current inventory of commercial spent fuel represents only about 1 percent of the volume of such defense waste. However, the current inventory of spent fuel already has a considerably higher level of radioactivity and heat output than the defense waste, and the annual discharge from the currently operating reactors exceeds the total defense waste inventory in those two measures. This is very significant for waste management, since the heat output is a more important factor than the physical volume of the waste in determining the amount of repository space needed for disposal.

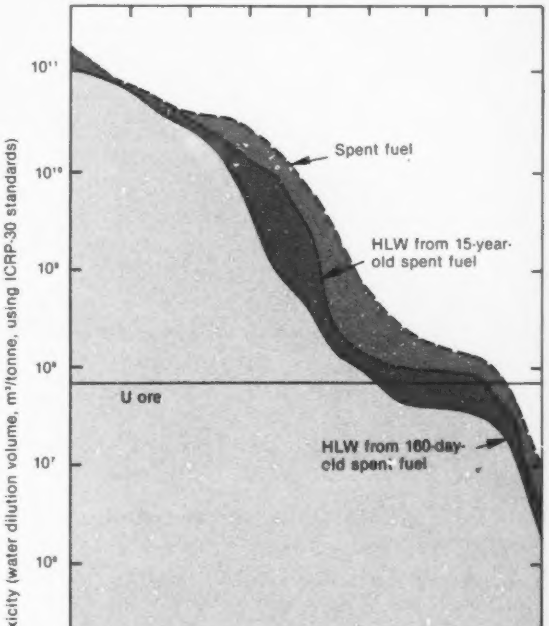
Hazards of Radioactive Waste

Comparison of Nuclear Waste to Uranium

While the original uranium in reactor fuel is itself a low-level health hazard, many of the radioisotopes produced by the fission of uranium or the conversion of uranium into transuranic elements are more toxic. First, most of these radioisotopes have shorter half-lives than that of uranium. Some of the fission products are so short-lived that about 80 percent are gone by the time the spent fuel is removed from the reactor.[10] This means that they undergo more radiation-producing decays per second than the original ore; hence, their radioactivity per gram of material is much higher. Second, some of the waste products are more biologically dangerous than the original uranium because of the intensity of radiation emitted and because they stay in the body longer, once ingested, or concentrate in particularly vulnerable organs. For example, 1 curie of the transuranic isotope americium-241 (Am^{241}) is estimated to be about 10 times as hazardous as 1 curie of U^{238}.[11]

The hazard posed by radioactive waste is often discussed in terms of an overall measure, or index, of the toxicity of the waste. A commonly used measure of toxicity is the water dilution volume (WDV), defined as the volume of water (usually measured in cubic meters) that would be required to dilute the waste to acceptable drinking standards. Figure 2-3 shows the WDV for 1 tonne of spent fuel, for the high-level waste that would result if the spent fuel were reprocessed both 160 days and 15 years after discharge from the reactor, and for the uranium ore needed to produce 1 tonne of fuel. Those WDVs are calculated using standards based on recent data for toxicity of various radioisotopes.[12] Figure 2-2 shows that it would take about 1 million years for high-level waste from reprocessing 15-year-old spent fuel to fall below the toxicity of the

Figure 2-3.—Toxicity of Spent Fuel, High-Level Waste, and Its Parent Uranium Ore



SOURCE: Data supplied by Oak Ridge National Laboratory.

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[10] Bernard L. Cohen, "High-Level Radioactive Waste From Light-Water Reactors," *Reviews of Modern Physics*, vol. 49, No. 1, January 1977, pp. 1-19.

[11] International Commission on Radiation Protection, *Limits for Intakes of Radionuclides by Workers*, ICRP-30 (New York: Pergamon Press, 1979).

[12] Ibid.

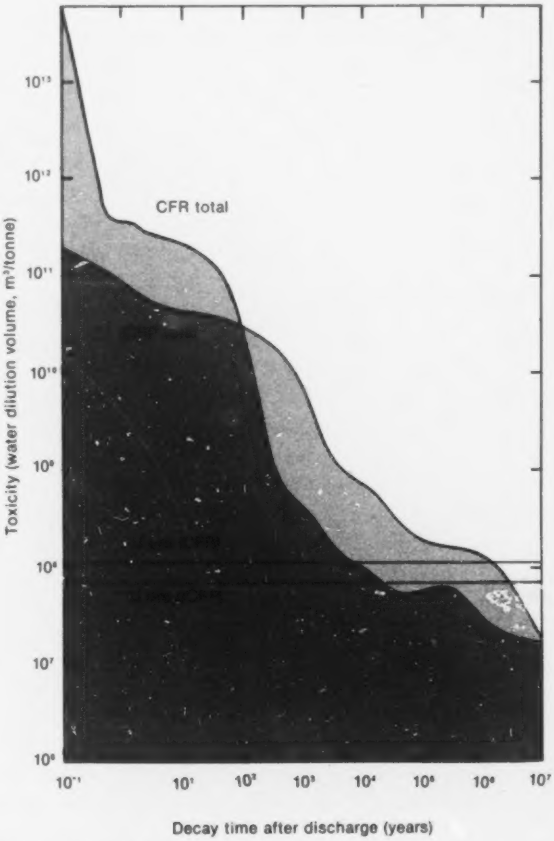
original ore. The toxicity of the unreprocessed spent fuel would fall below that of the original ore after about 3 million years. The figure also shows that following the decay of most of the fission products in the first few hundred years, the toxicity of spent fuel would exceed that of the waste from reprocessing 15-year-old fuel by a factor of from 2 to 5.

Such comparisons of spent fuel and high-level waste with each other and with uranium ore in terms of a simple toxicity index should be used only with great caution, for several important reasons. First, these comparisons may be somewhat misleading since a toxicity index such as the WDV is only a crude measure of the *potential* hazard to humans. It will greatly overestimate the actual hazard posed by the waste, which must take into account how likely it is that the waste will be released into the biosphere and eventually be ingested by humans. A discussion of the hazard from radioactive waste that considers the barriers between the waste and human beings is contained in chapter 3.

Second, there are substantial uncertainties in the estimates of the risk of cancer per curie of any radioisotope ingested into the body, resulting from uncertainties about: 1) the fate of the radioisotope in the body (what fraction is taken into the system, where it goes, and how long it stays there), and 2) how much damage is done by the radiation the radioisotope emits.[13] As new data and extrapolation methods become available, estimates of the toxicity of various radioisotopes change over time. These uncertainties about the toxicity of the waste and the likelihood of additional revisions in toxicity estimates in the future[14] strongly suggest that waste management regulations and policies be designed to be relatively immune to such changes.

The impact of such changes can be seen by considering the effects of the recently revised estimates published by the International Commission on Radiation Protection (ICRP), which are reflected in figure 2-2. Except for a few recent studies,[15] most published analyses use older estimates such as those underlying Nuclear Regulatory Commission (NRC) standards for protection of the general public, contained in the Code of Federal Regulations (CFR).[16] The effect of the recent changes is shown in figures 2-4 and 2-5, which display the toxicities of spent fuel and high-level waste from reprocessing that spent fuel 160 days after discharge from the reactor, calculated using both the ICRP and the CFR standards. These figures show that the

Figure 2-4.—Toxicities of PWR Spent Fuel and Its Parent Uranium Ore



SOURCE: National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes*, 1983.

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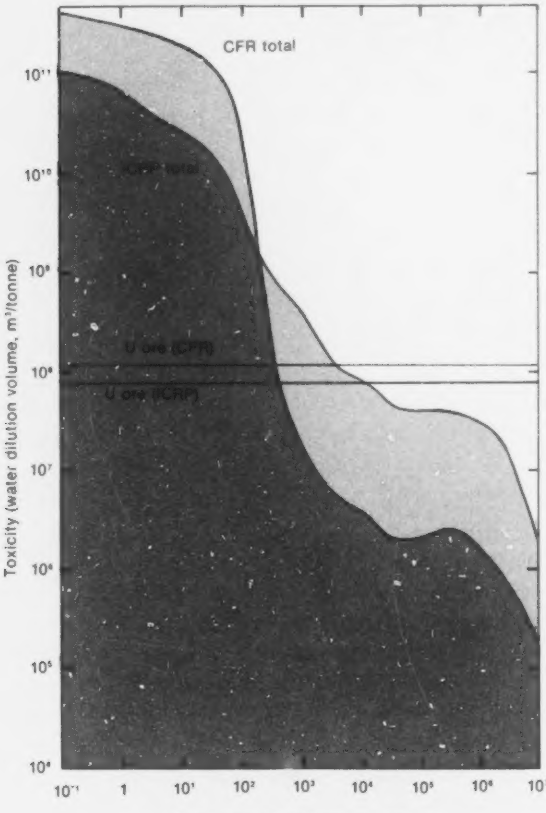
[13] Bernard L. Cohen, "Effects of ICRP Publication 30 and the 1980 BEIR Report on Hazard Assessments of High-Level Waste," *Health Physics*, vol. 42, No. 2, February 1982, pp. 133-143; and National Research Council, op. cit., app. B. See also Charles E. Land, "Estimating Cancer Risks From Low Doses of Ionizing Radiation," *Science*, vol. 209, September 12, 1980, pp. 1197-1203.

[14] A discussion of the possible need for further revisions of the ICRP-30 estimates of the toxicity of Np^{237} is found in Bernard Cohen, "Effects of Recent Neptunium Studies on High-Level Waste Hazard Assessments," *Health Physics*, vol. 44, No. 5, May 1983, pp. 567-569.

[15] Cohen, "Effects of ICRP 30;" National Research Council, op. cit.; A. G. Croff, "Potential Impact of ICRP-30 on the Calculated Risk From Waste Repositories," *Transactions of the American Nuclear Society*, vol. 39 (1981), pp. 74-75.

[16] 10 CFR 20, app. B, table II.

Figure 2-5.—Toxicities of PWR High-Level Waste and Its Parent Uranium Ore



SOURCE: National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes*, 1983.

ICRP estimates decrease the toxicity of both spent fuel and high-level waste for the first few hundred years, but increase it in the long-run, with a greater increase for high-level waste than for spent fuel. For example, the amount of time it takes for each to decay to the toxicity of uranium ore is increased—from about 7,000 years to about 3 million years for spent fuel, and from about 400 years to about 20,000 years for high-level waste.

Third, comparisons between the toxicity of spent fuel and high-level waste from reprocessing are also sensitive to the underlying assumptions regarding reprocessing and recycle of the separated plutonium that affect the actual radionuclide content of the high-level waste. For example, the toxicity of high-level waste is highly dependent on the assumed delay in reprocessing spent fuel after it is discharged from the reactor. The longer the delay, the less the difference between the toxicity of the resulting high-level waste and the original spent fuel. Delay allows 14-year-half-life plutonium-241 (Pu^{241}) in the spent fuel to decay into Am^{241}, which will be separated into the high-level waste. Am^{241} and its decay product neptunium-237 (Np^{237}) are the principal contributors to the long-term toxicity of both spent fuel and high-level waste.[17]

This effect can be seen by comparing the two curves for high-level waste shown in figure 2-3. These figures show that increasing the delay before reprocessing from 160 days to 15 years increases the time required for the toxicity of the high-level waste to decrease to that of the original ore from about 20,000 years to about 1,000,000 years. Most published comparisons of the toxicity of spent fuel and high-level waste assume that reprocessing occurs a short time (from 150 days to about 1.5 years) after discharge from the reactor, which was originally expected to be the normal case for operation of commercial reactors with recycle. This tends to maximize the difference in toxicity between the spent fuel and the resulting high-level waste. However, the delays that have already occurred in the initiation of large-scale commercial reprocessing make it unlikely that fuel younger than 15 years old would be routinely reprocessed in the United States for decades after reprocessing began.[18] Thus, the curve for high-level waste from 15-year-old spent fuel in figure 2-3 represents a more realistic estimate of the toxicity of the high-level waste that might actually be produced by reprocessing commercial spent fuel in the United States during this century.

Finally, the radionuclide content, and thus the toxicity, of high-level waste will depend heavily on the extent to which the plutonium that is separated from the spent fuel during reprocessing is recycled in MOX fuel. The reason that high-level waste is less toxic than the spent fuel from which it is derived is that reprocessing removes practically all of the plutonium, which not only is highly toxic itself, but also decays to form other toxic radioisotopes. However, unless that plutonium is recycled and destroyed by fission in a reactor, it would eventually have to be disposed of in addition to the high-level waste. In other words, reprocessing by itself simply separates the plutonium from the fission products and other TRU elements in the spent fuel, but does not eliminate it. The additional step of recycling the plutonium would be required to reduce the amount of plutonium that must ultimately be disposed of. However, plutonium recycle increases the toxicity of the resulting high-level waste compared to that produced from reprocessing fuel containing only uranium, since it increases the amounts of important transuranic elements in the waste.[19] As a result, the net reduction in waste toxicity that will result from reprocessing and recycling will be less than that implied by comparisons (e.g., those shown in fig. 2-3) which consider only the high-level waste resulting from fuel that contains only uranium.

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[17] Earlier reprocessing alone, unaccompanied by early recycle of the plutonium, would not avoid this effect, since the plutonium-241 in the separated plutonium would continue to decay into americium-241 which would have to be disposed of in high-level waste sooner or later. While rapid recycle of the plutonium could fission the plutonium-241 before it could decay, recycle itself complicates the waste disposal task in ways that could offset this advantage. This is discussed further in chapter 3.

[18] National Research Council, op. cit., p. 34.

Comparison of Radioactive and Other Toxic Waste

Comparing radioactive waste to other hazardous industrial waste provides some perspective on the problem of radioactive waste management.[20] Hazardous wastes include organic materials (e.g., chlorinated hydrocarbons) and inorganic chemical components—almost all of which, like radioactive waste, are manmade and do not exist in the natural environment—and metals, such as barium and arsenic, which occur naturally, but usually in chemically bound forms. Both radioactive and other toxic wastes can cause cancer, birth defects, and genetic mutations, although the causal relationships for such effects may be better understood in the case of radioactive materials.[21]

Unlike many toxic organic and inorganic compounds, radioactive waste cannot readily be detoxified or destroyed.[22] As a result, it must be isolated from the environment until it decays spontaneously to low levels of radioactivity. Because radioactive waste eventually decays, it is unlike some organic and inorganic compounds, which persist indefinitely unless some treatment is applied to them, and unlike the toxic metals, which persist forever, although they too can be stabilized or immobilized to render them relatively harmless. This spontaneous decay, however, produces the radiation that makes the material toxic and releases heat. Both the radiation and the heat complicate the task of disposal (see ch. 3).

The amount of high-level radioactive waste generated each year is much less than the amount of other hazardous wastes. In 1983 about 1,400 tonnes of spent fuel were generated compared to 255 million to 275 million tonnes annually of other hazardous wastes.[23] On the other hand, the cost of disposing of the small amount of radioactive waste is much higher than for other hazardous waste, because of the differences in disposal techniques that must be used. The current cost estimate for disposal of spent fuel or equivalent reprocessed waste in a deep geologic repository is about $125,000 per tonne,[24] compared to estimates of up to $240 per tonne for shallow landfill disposal of other hazardous wastes and up to $791 per tonne for treatment of such wastes.[25] Considering that the generation of about $10 million worth of electricity produces only 1 tonne of spent fuel,[26] it is possible to spend such a large amount per tonne to dispose safely of spent fuel, or high-level waste from that spent fuel, without materially affecting the overall cost of nuclear electricity.

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[19] For example, Am^{241}, which is a major contributor to long-term toxicity both directly and through daughter Np^{237}, would be increased about threefold by plutonium recycle in light-water reactors. See National Research Council, op. cit., pp. 289-290. See the analysis of reprocessing in ch. 3, for further discussion of the effects of reprocessing time and plutonium recycle on the overall high-level waste management problem.

[20] For a detailed analysis of the problems of hazardous waste management, see *Technologies and Strategies for Hazardous Waste Control* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-M-196, March 1983). For a more extensive comparison between nuclear and nonnuclear hazardous wastes, see James P. Murray, Joseph J. Harrington, and Richard Wilson, "Risks of Hazardous Chemical and Nuclear Waste: A Comparison," Discussion Paper E-82-11, Energy and Environmental Policy Center. Harvard University, November 1982.

[21] Land, op. cit.; and Thomas H. Maugh, II, "Chemical Carcinogens: How Dangerous Are Low Doses?" *Science*, vol. 202, Oct. 6, 1978, pp. 37-41.

[22] By bombarding radioactive waste with neutrons, some of the long-lived, highly toxic transuranic elements can be split, leaving fission products with short half-lives that decay much more rapidly. However, this does not now appear to be a practical method for reducing the long-term toxicity of radioactive waste. See discussion of "transmutation" in ch. 3. See also, A. G. Croff, J. O. Blomeke, and B. C. Finney, *Actinide Partitioning Transmutation Program Final Report, I: Overall Assessment*, ORNL-5566 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, June 1980).

[23] Office of Technology Assessment, op. cit., p. 3.

[24] U.S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020, June 1983, p. 14.

[25] Office of Technology Assessment, op. cit., table 34, p. 196.

Because radioactive waste is more tightly controlled and regulated than other hazardous wastes, the location and characteristics of virtually all radioactive waste are known,[27] and there is little chance of illegal or uncontrolled dumping of significant quantities, as sometimes occurs with other toxic waste. Radioactive materials are also relatively easy to detect in small concentrations using readily available instruments such as the Geiger counter; thus, the potential threat of any escaped waste can be checked more easily. In contrast, detection of the many more diverse nonradioactive hazardous materials is more difficult; no universal method analogous to a Geiger counter exists to detect easily and economically the many potentially toxic chemicals that might be released, or that have already been released, by hazardous wastes.

INSTITUTIONAL ASPECTS OF WASTE MANAGEMENT

Waste management includes not only the technical activities for treating and isolating nuclear waste but also a range of institutional activities required to guide and support them.[28] These are described briefly below and are discussed at greater length in chapters 7 and 8.

Federal Activities

Policymaking

Policymaking or decisionmaking activities at various administrative levels control the overall structure and goals of the system, the integration of the activities, and, to a certain extent, the degree to which the activities are accomplished successfully. Because final isolation of high-level radioactive waste is a Federal responsibility, policymaking in this area is principally a Federal activity, although there is much involvement by non-Federal actors. Even waste management activities under private control, such as interim spent fuel storage, are subject to Federal regulation. The Federal Government's authority for commercial radioactive waste management rests with Congress and the executive branch. Congress establishes general policy through legislation and controls program implementation by reviewing, authorizing, and appropriating resources. The laws passed by Congress authorize Federal agencies to carry out their responsibilities, clarify Federal and State roles in making decisions and implementing programs, and give States legal authority over certain waste management activities. The President and the executive branch further develop and implement the waste management programs.

Regulation

ESTABLISHMENT OF SAFETY REQUIREMENTS

The Environmental Protection Agency (EPA) is responsible for developing generally applicable standards that set limits on the allowable release of radioactivity from the disposal of radioactive waste. Proposed numerical standards for high-level waste disposal in geologic repositories were published for comment in December 1982, and final criteria are expected to be promulgated in 1985. NRC is responsible for developing regulations based on EPA standards for managing high-level radioactive waste. Final NRC regulations for disposal in geologic repositories were issued in 1983.

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[26] The Department of Energy estimates that generation of about 28 trillion kilowatt-hours (kWh) of electricity by nuclear reactors will produce 144,000 tonnes of spent fuel, or an average of about 194 million kWh/tonne. DOE, *Report on Financing the Disposal*, p. 10. With an average charge for residential customers of electricity of 54 mills/kWh in calendar year 1980 (Congressional Budget Office, *Financing Radioactive Waste Disposal*, September 1982, p. xviii), this comes to total revenues of $10,480,000 per tonne of spent fuel generated.

[27] See DOE, *Spent Fuel and Radioactive Waste Inventories*, for a complete inventory of radioactive waste in the United States.

[28] A more detailed description of the institutional aspects of the Federal radioactive waste management program is found in *Information Base for Commercial Radioactive Waste Management*, U.S. Department of Energy, DOE IET/40110-1, July 1982.

Box C.—Congressional Committees Involved in Radioactive Waste Management

House of Representatives:

- Armed Services Committee. Jurisdiction over defense nuclear activities.
- Appropriations Committee. Appropriates funds for nuclear waste management programs.
- Interior and Insular Affairs Committee. Jurisdiction over the regulation of the domestic nuclear energy industry and oversight responsibilities for nonmilitary nuclear energy research and development, including the disposal of nuclear waste.
- Energy and Commerce Committee. Jurisdiction over regulation and use of nuclear facilities and use of nonnuclear energy.
- Rules Committee. Jurisdiction over procedures for congressional review of State objections to repository siting decisions.
- Science and Technology Committee. Jurisdiction over all energy research and development.

Senate:

- Armed Services Committee. Jurisdiction over defense nuclear activities.
- Appropriations Committee. Appropriates funds for nuclear waste management programs.
- Energy and Natural Resources Committee. Jurisdiction over nonmilitary development of nuclear energy.
- Environment and Public Works Committee. Jurisdiction over nonmilitary environmental regulation and control of nuclear energy.
- Governmental Affairs Committee. Jurisdiction over intergovernmental relations and nuclear proliferation issues.

The U.S. Department of Transportation (DOT) and NRC share responsibility for developing, regulating, and enforcing safety standards for transportation of such waste.

LICENSING

NRC is responsible for licensing the receipt and possession of commercial spent fuel and of nuclear waste at facilities for the long-term storage or disposal of high-level radioactive waste from any licensed activities and defense programs. NRC has already developed procedures and regulations (based on anticipated EPA standards) that must be satisfied before a mined geologic repository can be licensed. During the various steps of repository development, NRC may conduct hearings so that other interested parties may participate in licensing activities.

During the development of a repository, NRC will formally evaluate the suitability of potential sites at three stages. If the site appears suitable after in situ testing, NRC will issue a construction authorization for repository development. If the initial phases of repository construction pass NRC requirements, NRC will issue an operating license, and waste emplacement in the repository will commence. If the final predictions of repository performance after waste emplacement meet NRC requirements, NRC will authorize closure of the repository.

Development and Operation of Repositories

DOE is the Federal agency with lead responsibility for carrying out the high-level radioactive waste management policies adopted by Congress and the administration. The principal activity of DOE and its predecessors (the Atomic Energy Commission and the Energy Research and Development Administration) in this area has been research directed toward siting and constructing one or more geologic repositories for waste disposal. Other Federal agencies, in particular the Department of the Interior, also have some responsibilities in developing repositories.

Funding

Until 1983, funds for developing final isolation facilities came from annual Federal appropriations, with the assumption that the utilities using those facilities would ultimately repay the costs when they delivered waste to a Federal repository. Legislation enacted by Congress at the end of 1982 provides funds through user fees paid by utilities at the time the waste is generated.

Coordination and Management

Although DOE is the lead agency for waste management and Federal interagency cooperation on some waste management activities does exist, there

Box D.—Activities of Federal Agencies in the Development of a Geologic Repository

Department of Energy:

- Site characterization and selection
- Land acquisition
- Technology development
- Application for license
- Repository design, construction, operation, and closure
- Interactions with State/Indian tribes

Nuclear Regulatory Commission:

- Regulation promulgation
- Siting review
- Licensing proceedings
- Technology review
- Interactions with State/Indian tribes

Environmental Protection Agency:

- Standard promulgation

Department of the Interior:

- Site characterization support
- Land access
- Land withdrawal

SOURCE: Department of Energy.

is no single Federal agency with overall responsibility for coordinating and managing the activities of all the Federal agencies involved in waste management. Interagency coordination is discussed further in chapter 7.

Non-Federal Involvement

Intergovernmental Interaction

Among the most important non-Federal actors in waste management are the governments of the States, Indian tribes, and localities that may be affected by waste management activities. State, local, and Indian tribal governments informally review policy and programs and express concerns by direct appeal to Federal officials, by intervention in site selection processes, and, in the case of States, by passing legislation restricting waste management activities. Twenty-six States, in accordance with formal agreements with the Federal Government, can license uranium milling operations, decommissioned facilities, or commercial burial sites for low-level waste within their State boundaries. State officials have had a major impact on repository siting activities in the past, and the Nuclear Waste Policy Act of 1982 gives a major formal role to States and affected Indian tribes in those activities in the future. The role of State and tribal governments is discussed in chapter 8.

Public Involvement

Interest groups and the general public participate in waste management activities in many ways, including attendance at public hearings sponsored by Federal agencies, direct appeal to Members of Congress and other Federal and State officials, participation on citizen advisory panels and quasi-oversight panels, litigation, and submission of written comments on proposed activities as part of the National Environmental Policy Act process. Technical groups conduct independent studies and reviews and provide advice, either formally as contractors or informally through independent publications. Although there is much controversy over the role of the public in the decisionmaking process, some funds are available to State and local organizations

Box E.—Representative Non-Federal Participants in Waste Management

- Scientific organizations, such as the National Academy of Sciences and the American Association for the Advancement of Science.
- Industry and trade associations, such as the Atomic Industrial Forum and the Edison Electric Institute. Individual industries and utilities also may be influential.
- Environmental and public interest groups, such as the Natural Resources Defense Council and the Union of Concerned Scientists.
- Organizations representing State or local governments, such as the National Governors' Association and the National Conference of State Legislatures. Individual States also may be influential.
- Ad hoc citizen groups formed in areas of actual or potential radioactive waste management activities, such as Appleseed near Morris, Ill.
- Individual citizens.

(from the Federal Government) and to intervenor groups (from private sources) to facilitate non-Federal participation in waste management. Public involvement is discussed further in chapter 8.

International Activities

There are approximately 290 commercial nuclear powerplants in operation worldwide and another 215 plants under construction in 31 countries, including the United States.[29] Five countries have operating facilities for reprocessing spent fuel from LWRs. Major commercial waste management R&D is being undertaken by the United States, France, West Germany, Great Britain, Sweden, Canada, and Japan.[30] In the United States, DOE is primarily responsible for conducting cooperative R&D efforts with foreign countries. The Department of State is involved in waste management activities that involve U.S. nonproliferation policies or cooperative activities with other countries.[31] The Nuclear Waste Policy Act of 1982 includes provisions (sec. 223) to promote additional cooperation with nonnuclear weapon states in the field of spent fuel storage and disposal.

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[29] These figures were valid at the end of 1982. *International Atomic Energy Agency Bulletin*, vol. 25, No. 1, March 1983, p. 38.

[30] See K. M. Harmon, "Survey of Foreign Terminal Radioactive Waste Storage Programs," in U.S. Department of Energy, *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting*, CONF-831217, February 1984, pp. 199-205.

[31] On the subject of nonproliferation in general, see Office of Technology Assessment, *Nuclear Proliferation and Safeguards* (New York: Praeger Publishers, 1977). Detailed analysis of the relation between nuclear nonproliferation and spent fuel management is found in Frederick C. Williams and David A. Deese, *Nuclear Nonproliferation: The Spent Fuel Problem* (New York: Pergamon Press, 1979).

CHAPTER NOTE

The precise amount of spent fuel discharged by a reactor each year will depend primarily on two factors: the total amount of electricity generated by the reactor that year and the burnup of the fuel (measured in megawatt-days per tonne [MWd/t]), which is a measure of the amount of electricity obtained from each tonne of fuel (and thus of the amount of fissile material in the fuel that is used before the fuel is discharged from the reactor). The higher the burnup, the more complete the utilization of U^{235} and the less the discharge of spent fuel per gigawatt-year (GW-yr) of electricity generated. Since BWRs use lower burnups than PWRs, they discharge more spent fuel per GW-yr of generated electricity.

The 1984 DOE spent fuel projections shown in table 2-2 assume that spent fuel burnup will increase at an annual rate of 2.5 percent from 1985 to 1996, and will be 42,000 MWd/t for PWRs and 37,000 MWd/t for BWRs from 1996 on.[32] It is possible that burnups will increase even further in the future, perhaps up to 50,000 MWd/t, if the price of uranium, and thus of fresh fuel, goes up.[33] In this case, the amounts of spent fuel resulting from the projected levels of generation could be reduced somewhat. However, even though higher burnups would reduce the amount of spent fuel, they would not reduce the amount of fission products and transuranic elements contained in the spent fuel, since the amount of those isotopes created is approximately proportional to the amount of electricity generated. Use of higher burnups simply means that there will be more fission products and transuranics in each of the smaller number of fuel assemblies discharged for each gigawatt-year of electricity produced. In other words, the waste produced by generation of a given amount of electricity would be concentrated in a smaller amount of spent fuel if a higher burnup were used. Thus, the total heat output from the waste produced in generating a gigawatt-year of electricity, and the total repository space needed for disposal, would be relatively unaffected by increasing the burnup. However, handling and packaging at the repository might be simplified somewhat by the smaller number of spent fuel assemblies involved if they were disposed of directly without reprocessing. For this reason, there may be waste management incentives for increasing burnups beyond the levels that would be justified by the increased efficiency of fuel use alone.

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[32] U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories*, p. 11.

[33] U.S. Department of Energy, *Nuclear Proliferation and Civilian Nuclear Power*, vol. 9, June 1980, pp. 24-27.

Chapter 3

Technology of Waste Management

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Chapter 3

Technology of Waste Management

WASTE DISPOSAL

Over the last three decades, the Federal Government has considered disposing of radioactive waste permanently in geologic formations on land, in ice sheets, beneath the ocean floor, and in outer space. Although total containment of radioactive material in any of these environments may be impossible to guarantee, or even expect, these disposal environments are attractive because their remoteness from the Earth's surface minimizes the biological impacts of any potential releases of radioactivity.

Methods of disposal are in various stages of conceptual development. Disposal in mined geologic repositories is the concept most studied, and subseabed disposal is the next. In general, past Federal programs for waste disposal have concentrated almost exclusively on the development of mined geologic repositories. In 1981 this technology was formally selected as the focus of the Federal high-level waste management strategy by the U.S. Department of Energy (DOE), based on its Final Environmental Impact Statement (FEIS) on the Management of Commercially Generated Radioactive Waste, published in 1980.[1] However, very little work has been done on any of the other concepts except subseabed disposal. The uncertainties associated with many of the alternative disposal concepts reflect either the level of conceptual development of the technology or the complexity of the envisioned disposal system. In some cases, uncertainties can be resolved through additional research and development (R&D); in other cases, uncertainties may be unresolvable for all practical purposes.

Mined Geologic Repositories

Technology

The disposal of radioactive waste in mined geologic repositories at depths from 1,000 to several thousand feet below the Earth's surface is the final isolation technology most widely studied and favored by the worldwide scientific community. Three decades of study have revealed no insurmountable technical obstacles to the development of mined geologic repositories, provided suitable sites are found.[2]

The technology of the mined geologic repository is composed of a system of both natural and engineered barriers selected to prevent or limit the escape of waste from the repository so that the radiation exposure to humans from escaped waste is held to very low levels. In addition, geologic disposal also involves a "technology of prediction"—a set of procedures and techniques for predicting the performance of a repository over the very long time period that the waste remains hazardous. Each element of the technology of geologic repositories will be discussed briefly below.

NATURAL BARRIERS: THE SITE

The site of a mined geologic repository is an integral part of the technology of geologic disposal since it plays a crucial role in isolating the buried waste from the biosphere. For this reason, sites for such repositories must be selected with great care.

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[1] U.S. Department of Energy (DOE), *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste*, DOE/EIS-0046F (Washington, D.C.: October 1980), hereafter referred to as *FEIS*.

[2] Ibid; American Physical Society (APS), "Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management," *Reviews of Modern Physics*, vol. 50, No. 1, pt. II, January 1978; Interagency Review Group on Nuclear Waste Management (IRG), *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste*, TID-28818 (draft), (Washington, D.C.: October 1978); International Nuclear Fuel Cycle Evaluation (INFCE), *Waste Management and Disposal: Report of INFCE Working Group 7*, International Atomic Energy Agency (Vienna: 1980); U.S. Environmental Protection Agency (EPA), *Draft Environmental Impact Statement on 40 CFR Part 191, Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes*, EPA 520/1-82-025, December 1982, hereafter referred to as *DEIS on 40 CFR 191;* National Research Council, *A Review of the Swedish KBS-II Plan for Disposal of Spent Nuclear Fuel* (Washington, D.C.: National Academy of Sciences, 1980); National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, D.C.: National Academy Press, 1983); U.S. Nuclear Regulatory Commission, *Waste Confidence Decision, Federal Register*, vol. 49, No. 171, Aug. 31, 1984, pp. 34658-34688.

The natural features of the site that contribute to isolation are the host rock (which can be selected to prevent or minimize contact between the waste and flowing ground water, the principal potential mechanism for bringing buried waste into contact with human beings),[3] the chemical characteristics of the site and its environment (which can limit the rate at which the waste dissolves in ground water and is transported to the biosphere), and the time required for contaminated ground water to flow from the repository to the biosphere (which, along with the chemical characteristics of the media surrounding the repository, can delay the release of dissolved waste until many of the hazardous radionuclides have decayed). In addition, the location of the site can be selected to reduce the possibility of human intrusion (e.g., by avoiding proximity to valuable natural resources) and to provide for dilution of any contaminated ground water by large quantities of surface water before the ground water is used by human beings.

Until the late 1970's, the natural features of the geologic repository site were seen as the principal means for providing waste isolation. Initially, the emphasis was on a particular host rock, salt, which has features that were felt to provide adequate assurance that the waste would be isolated from contact with flowing ground water.[4] Later studies concluded that the characteristics of the environment surrounding the host rock could provide adequate isolation even if ground water were contaminated by contact with the waste and that there was no clearly superior host rock for mined repositories.[5] Other rocks under consideration include tuff (compacted volcanic ash), basalt (coarse-grained solidified lava), and granite.

Because the site plays such a central role in geologic disposal in mined repositories, the final validation of the concept will depend on construction and operation of a repository at an actual site.[6] No site has been approved for such a repository anywhere in the world, although some reviews have concluded that it will not be difficult to find suitable sites.[7] It is generally agreed that identification of specific sites for detailed geologic investigation is necessary to resolve the remaining technical questions about geologic disposal.[8]

In the United States, the process of finding suitable sites involves the screening and progressive elimination of sites in different regions of the country. It is likely that only a small percentage of the sites screened will survive the site selection process. Because of the high degree of variability among sites, each potential site must be evaluated individually through surface exploration and by geological mapping, geophysical (nondestructive) surveying, drilling, and in situ testing within candidate rock formations. The technology for identifying and "characterizing" potential sites is available or under development.[9]

The suitability and total waste capacity of each potential site must be evaluated on a case-by-case basis because of the great variability among sites. In some cases, for example, a fault (a fracture in the Earth's crust, along which there has been relative displacement of adjacent rock formations) may reduce the suitability of a particular site; in other cases, the fault could actually provide an additional natural barrier.

Because all potentially usable rock types have not been evaluated for repository sites, the total number and capacity of potential repository sites in the United States is unknown at this time. However, general knowledge about geologic formations throughout the United States suggests that at least several suitable repositories could be located, although it is probable that suitable sites cannot be found in all States.

ENGINEERED FEATURES

The principal engineered features are the overall design of the repository, the waste form (e.g., solidified high-level waste or unprocessed spent fuel), and the waste package, which may include an overpack (e.g., a titanium container) designed to provide containment for up to 1,000 years and a packing material (e.g., bentonite) designed to prevent water from reaching the overpack and to limit the escape of any water that does come into contact with the waste (see fig. 3-1).

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[3] APS, op. cit.

[4] See discussion of the evolution of the role of the waste form in app. A.

[5] Ibid.; IRG, op. cit.; National Research Council, *Isolation System*.

[6] INFCE, op. cit., p. 119.

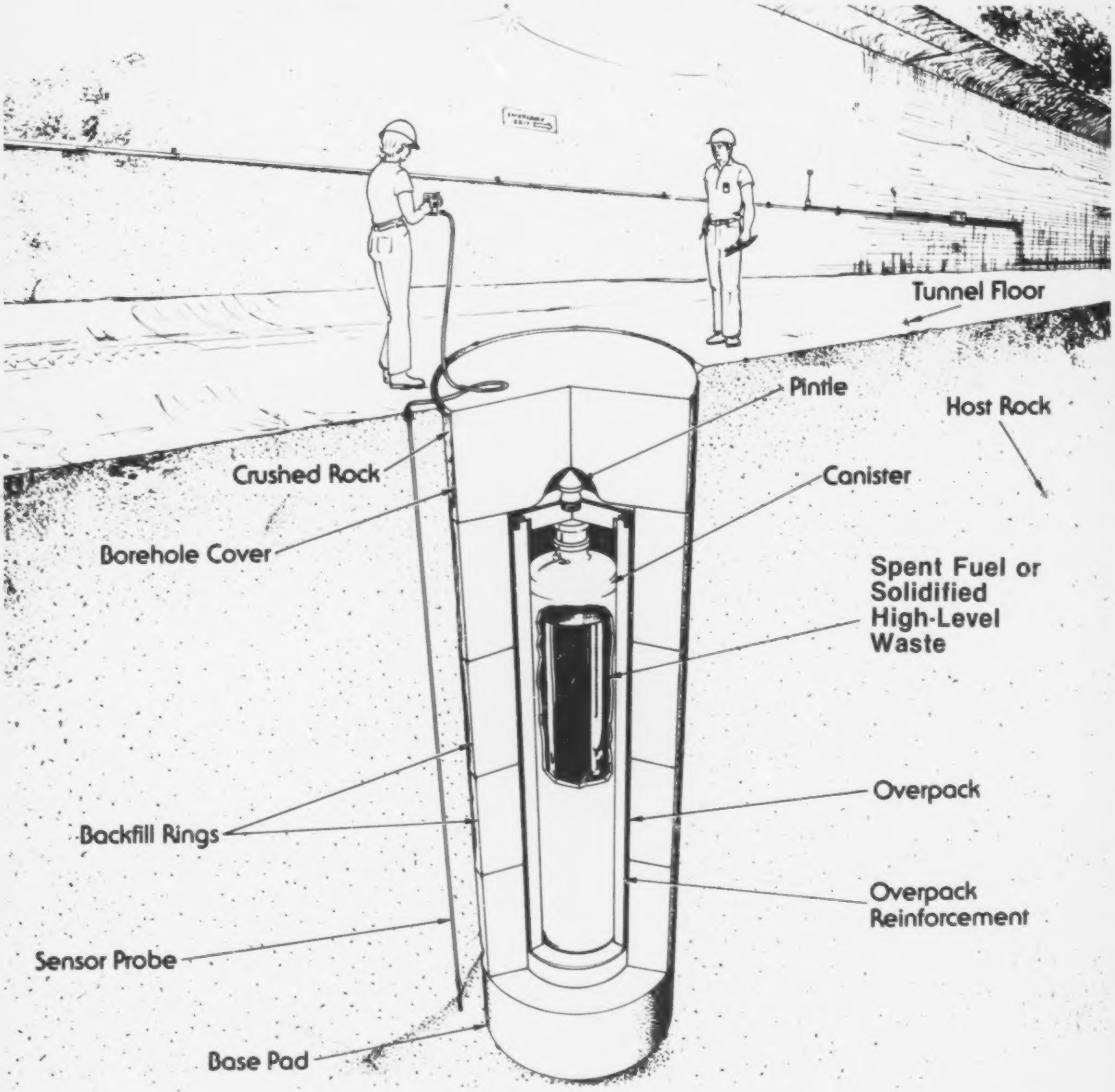
[7] APS, op. cit. The National Research Council review of a Swedish waste disposal plan also concluded that suitable disposal sites could be found in Sweden. National Research Council, *Review of the Swedish KBS-II Plan*.

[8] IRG, op. cit.; U.S. Department of Energy and U.S. Geological Survey (USGS), *Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository, Draft*, DOE/TIC-11033 (draft), April 1980, p. 1.

[9] Ibid.; Cyrus Klingsberg and James Duguid, *Status of Technology for Isolating High-Level Radioactive Wastes in Mined Repositories*, DOE/TIC 11207 (draft) (U.S. Department of Energy: October 1980).

As noted above, until the late 1970's, it was generally assumed that the natural geologic features of a salt repository alone would provide an adequate degree of isolation. The solid waste form (required

Figure 3-1.—Emplaced Waste Package


Tunnel Floor
Pintle
Host Rock
Crushed Rock
Canister
Borehole Cover
Spent Fuel or Solidified High-Level Waste
Overpack
Backfill Rings
Overpack Reinforcement
Sensor Probe
Base Pad

by Federal regulation) and waste package were intended only to prevent accidental release of waste during transportation and handling until retrieval of the waste from the repository was no longer contemplated. They were not seen as playing a crucial role in ensuring long-term isolation of the waste within the repository after it was sealed.[10]

In the mid-1970's to late 1970's, recognition of the uncertainties associated with the prediction of the behavior of the repository and surrounding geology over a period of many thousands of years led to a growing interest in a "multiple barrier" approach in which a combination of manmade and natural barriers would act together to provide confidence in long-term isolation, despite uncertainties about each barrier separately. The result has been a growing emphasis on the role of the waste form and the waste package,[11] which is reflected in Nuclear Regulatory Commission (NRC) regulations for geologic disposal.[12]

The current reference waste form for solidified high-level waste from reprocessing is borosilicate glass, which was selected when a solid waste form was seen as being needed primarily for safe transportation and handling. When the waste form took on an important role in long-term isolation, questions arose about how well borosilicate glass could perform this more demanding task under the conditions anticipated in a repository after closure. Of particular concern was the question of the rate at which waste might dissolve from the glass into ground water at the high temperatures that could be produced by the heat emitted by the waste.[13] Several technical reviews have concluded, however, that borosilicate glass could be an adequate waste form (although perhaps not the best one possible) if the repository were designed so that the temperature of the glass remained relatively low (around 100° C).[14] Recent studies have also concluded: 1) that development of a waste form that would release waste into ground water much more slowly than forms that are currently available could reduce substantially the expected long-term effects of geologic disposal, and 2) that improvements in the waste form would be much more effective than improvements in the rest of the waste package in achieving that result.[15] Further discussion of the value of continued R&D on alternative waste forms is found in chapter 6.

If reprocessing to recover plutonium and uranium does not occur, it is assumed currently that spent fuel would be disposed of directly, so that the waste form would be the uranium dioxide fuel pellets (still in the fuel assemblies) that contain the waste products. Recent analyses have concluded that adequate isolation can be achieved in this way, although the fuel pellets would be more soluble than borosilicate glass.[16] If necessary the spent fuel could be dissolved and resolidified in a better waste form.[17] However, a careful systems analysis would be necessary to determine if the increase in worker exposures and accident risks resulting from more complex waste-processing operations would offset the possible decrease in long-term risks from the waste after disposal.[18]

Some have argued that use of sophisticated engineered barriers, such as a low-solubility waste form or long-lived package, could decrease the reliance on natural barriers to the extent that many more sites would be usable for repositories.[19] (The role of long-lived waste packages in a conservative repository system design is discussed further in ch. 6.) While there is no consensus about the degree to which engineered barriers might substitute for natural ones, there is growing agreement that they may usefully complement natural ones to provide a high degree of isolation through a multiple-barrier system in which each barrier helps compensate for the uncertainties about the others.[20]

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[10] See app. A.

[11] See, for example, the proposed Swedish KBS waste disposal system in which major reliance is placed on a long-lived waste package, analyzed in National Research Council, *Review of the Swedish KBS-II Plan,* and in National Research Council, *A Review of the Swedish KBS-3 Plan for Final Storage of Spent Nuclear Fuel* (Washington, D.C.: National Academy Press, 1984).

[12] 10 CFR 60.

[13] See, for example, G. J. McCarthy et al., "Interactions Between Nuclear Waste and Surrounding Rock," *Nature*, vol. 273, May 18, 1978, pp. 216-217.

[14] National Research Council, *Isolation System*, p. 7; U.S. Department of Energy, *The Evaluation and Review of Alternative Waste Forms for Immobilization of High-Level Radioactive Wastes,* Report No. 3 by the Alternative Waste Form Peer Review Panel, DOE/TIC-11472, July 1, 1981.

[15] National Research Council, *Isolation System*, p. 280; EPA, *DEIS on 40 CFR 191*, p. 208.

[16] National Research Council, *Isolation System*; INFCE, op. cit.; IRG, op. cit.; EPA, *DEIS on 40 CFR 191*.

[17] DOE, *FEIS*, pp. 4.20-4.22.

[18] National Research Council, *Isolation System*, p. 14.

[19] See, for example, National Research Council, *Isolation System*, p. 45. However, this and other recent studies have concluded that it is very important to select a site with chemical characteristics that will limit the rate at which particularly toxic and long-lived radionuclides such as Np^{237} can dissolve into ground water. EPA, *DEIS on 40 CFR 191*, p. 109.

TECHNOLOGY OF PREDICTION

Development and operation of mined geologic repositories will require not only location of specific sites and design of engineered facilities appropriate for those sites but also decisions by the licensing authority, NRC, that those combinations of sites and engineered features can be expected to provide the required degree of waste isolation for a required period of time. In addition to the physical technology, therefore, a "technology of prediction" is needed to show in a formal licensing process that a proposed repository is likely to meet established standards.

The repository development and licensing process is uncharted territory. The ability of a geologic repository to isolate radioactive waste for millenia cannot be demonstrated directly in the same sense that a new aircraft can be demonstrated to perform according to its design specifications. For this reason, there must be heavy reliance on predictions of the long-term isolation provided by the repository based on the use of mathematical models that embody scientific understanding of the behavior of the repository and its environment.[21] Techniques for predicting repository performance are needed as a basis for detailed design of a repository, as well as for the licensing process.[22] Such long-term prediction has never been done in a formal regulatory process, and no widely reviewed and generally accepted method for predicting repository performance exists. Many analytic procedures to be used in the licensing process must be developed, including data collection and validation techniques, methods for verifying and validating scientific models, and the formal procedures for using such models to predict repository performance.[23] The importance of an explicit program to develop the technology of prediction is discussed in chapter 6.

OVERALL STATE OF TECHNOLOGY

No licensed mined repository for high-level radioactive waste exists in the United States or elsewhere in the world. The failure to develop and license mined repositories in the United States stems to a large extent from nontechnical factors such as inadequate and intermittent Federal support and reluctance to address major institutional problems. The main areas of technical disagreement concern not the ultimate feasibility of developing mined repositories, but the degree of conservatism in design (e.g., temperature limits and the design requirements for engineered barriers) and the pace and scope of the R&D program needed to develop a repository safely.[24] Technical reviews have concluded that the major remaining technical uncertainties about geologic disposal could be sufficiently resolved in time to allow the first repository to be constructed and licensed for operation by the late 1990's, if no unforeseen technical or institutional problems arise.[25]

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[20] Both proposed EPA criteria for geologic disposal, and final NRC regulations place emphasis on use of a multiple-barrier approach. See proposed EPA standards in the *Federal Register*, vol. 47, No. 250, Dec. 29, 1982, pp. 58196-58206. Final NRC technical criteria, 10 CFR, pt. 60, are found in *Federal Register*, vol. 48, No. 120, June 21, 1983, pp. 28194-28229, and are summarized in app. D.

[21] IRG, op. cit.; APS, op. cit.; Klingsberg and Duguid, op. cit.; National Research Council, *Isolation System*; EPA, *DEIS on 40 CFR 191*.

[22] Thomas H. Pigford, "The National Research Council Study of the Isolation System for Geologic Disposal of Radioactive Wastes," presented at the meeting of the Materials Research Society, Boston MA, November 1983.

[23] See National Research Council, *Implementation of Long-Term Environmental Radiation Standards: The Issue of Verification* (Washington, D.C.: National Academy of Sciences, 1979), for detailed discussion of steps needed in demonstrating compliance with criteria.

[24] For example, the authors of a USGS report that is cited sometimes as raising fundamental questions about the overall concept of geologic disposal believe that acceptable geologic repositories can be constructed. J. D. Bredehoeft et al., "Geologic Disposal of High-Level Radioactive Wastes—Earth Science Perspectives," *Geological Survey Circular 779*, U.S. Geological Survey, undated, p. III. Also, as noted above, the questions about the suitability of borosilicate glass as a waste form relate to its performance at very high temperatures and can be dealt with by keeping the temperature in the repository low. The extensive debates about waste management policy during the Carter administration dealt not with whether to develop geologic repositories, but instead with how many sites and geologic media should be examined before selecting a site. IRG, op. cit.

[25] DOE and USGS, op. cit., p. 1, concludes that 10 years (from 1980) should be needed to resolve the major technical uncertainties.

TECHNOLOGY DEPLOYMENT

Disposal in mined geologic repositories will involve the following activities (as well as others listed in ch. 2):

Disposal Technology Development and Siting.—DOE's present R&D efforts are focused on spent fuel transportation and storage; data collection on geohydrologic environments and waste/rock interactions; the development and evaluation of waste forms, canisters, and other engineered barriers; the development of equipment and facility designs for waste handling, processing, and disposal; and the development of predictive mathematical models for evaluating the suitability of potential repository sites. Information from in situ testing and impact evaluation activities at potential sites will be used by DOE to develop full-scale repository designs to be submitted to NRC for approval. According to current regulatory procedures,[26] if a potential repository site and design met appropriate NRC requirements, NRC would authorize construction. After some or all of the repository and supporting surface facilities were constructed, NRC would thoroughly evaluate the suitability of the site and determine whether to approve emplacement of waste in the repository.

Repository Development and Operation.—Repository development would involve excavating rock from the repository, preparing (canning) the waste in surface facilities at the repository site, lowering the canisters of waste into the repository, and emplacing the canisters of waste and the surrounding overpack material into holes drilled in the rock formation (see fig. 3-2). Each repository would remain in operation from 10 to 40 years, depending on its size and the rate of waste emplacement. During this operational phase, additional information on the behavior of the repository would be collected and used to refine further the predictions of the long-term behavior of the repository. Individual rooms or modules of the repository could be backfilled or kept open for a certain period of time to permit further cooling of the waste or to maintain ready access to the waste.

After the repository is filled, DOE could request that its license be amended to permit decommissioning or closure of the facility. NRC would make a decision about the request after considering the plan and the public comments about it in light of NRC requirements. The tunnels connecting individual rooms or modules of the repository would then be backfilled and the vertical access shafts to the repository, permanently sealed. After closure, monitoring could be used to detect unexpected releases from the repository.

Safety

The expected efficacy of geologic disposal is not based on the conclusion that the waste can be contained completely until it decays to harmlessness. Instead, *it is assumed that some releases may occur and that engineered and natural barriers can limit the size of such releases to very low levels.* The two principal modes of possible release of radioactivity from a well-designed and well-sited mined repository would be small, concentrated releases from human intrusion (e.g., from digging a well near or into a repository), which could expose a few individuals to relatively large doses of radiation, or the gradual release of radioactivity from the repository into ground water (and, ultimately, into drinking water or food supplies), exposing a potentially large population to very small doses (compared to background radiation).[27] The release of a large fraction of the waste in a repository would be extremely unlikely, and the chance that any individual would receive a very high dose of radiation would be small.[28]

The U.S. Environmental Protection Agency (EPA) has calculated that releases from a geologic repository containing 100,000 metric tons (tonnes) of spent fuel (the lifetime output of about 100 one-gigawatt [GWe] reactors) could be expected to produce fewer than an average of one fatal cancer every 10 years over a 10,000-year period. Table 3-1 shows that this level of health effects is smaller than the health effects that could result from other sources of ionizing radiation. For example, it is much less than 1 percent of the fatal cancers that would be produced in the same exposed population from normal levels of background radiation.[29] The results

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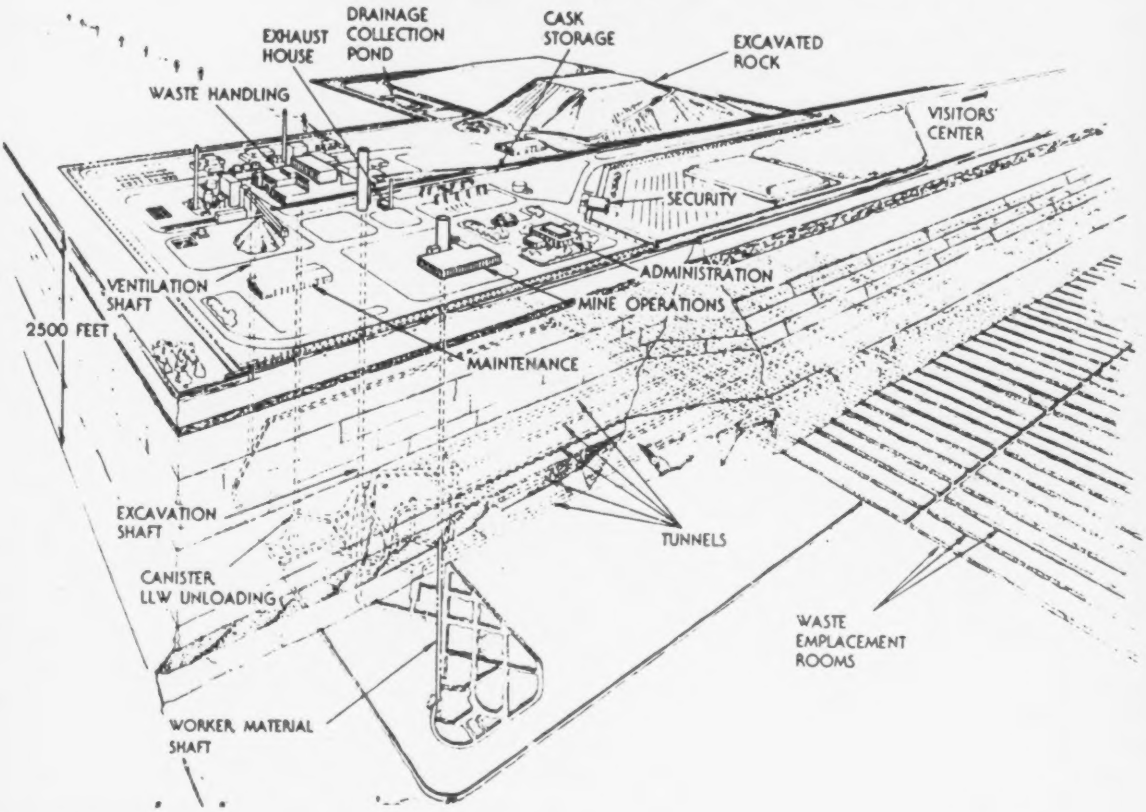
[26] 10 CFR 60, Subparts B and C, published in 46 FR 13971, Feb. 25, 1981.

[27] EPA, *DEIS on 40 CFR 191; National Research Council, Isolation System*.

[28] EPA, *DEIS on 40 CFR 191*, pp. 107-108.

[29] Ibid., p. 43.

Figure 3-2.—Artist's Conception of the Surface Support Buildings and Underground Facilities of a Radioactive Waste Repository


DRAINAGE COLLECTION POND
EXHAUST HOUSE
CASK STORAGE
EXCAVATED ROCK
WASTE HANDLING
VISITORS' CENTER
SECURITY
ADMINISTRATION
VENTILATION SHAFT
MINE OPERATIONS
2500 FEET
MAINTENANCE
EXCAVATION SHAFT
TUNNELS
CANISTER LLW UNLOADING
WASTE EMPLACEMENT ROOMS
WORKER MATERIAL SHAFT

SOURCE: U.S. Department of Energy.

of EPA's calculations for various geologic media are shown in table 3-2. More recent analysis, which takes into account the revised estimates of radionuclide toxicity discussed in chapter 2, supports EPA's conclusions that the expected effects from a well-designed and well-sited repository would be small compared to the effects from background radiation.[30]

Figures 3-3 and 3-4 show recent estimates of the possible performance of a repository in basalt containing 100,000 tonnes of spent fuel or equivalent high-level waste (solidified in borosilicate glass). Performance is measured in terms of the maximum radiation doses, in millirems per year, that would be received by an individual from water contaminated by waste that has escaped from the repository. The calculations reflect the recent International Commission on Radiation Protection revisions of the estimated toxicity of critical radionuclides that were discussed in chapter 2. Both figures show that the longer it takes for water to travel from the repository to the environment where it can be ingested by humans, the lower the predicted dose, because of radioactive decay during that time. They also show that the dose from spent fuel is expected to be higher than that from high-level waste. However, even for spent fuel, the predicted dose from using contaminated surface water is at most around 10 millirems per year, compared to a normal dose of around 110 millirems per year from normal back-

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[30] National Research Council, *Isolation System*, ch. 9.

Table 3-1.—Number of Possible Cancer Cases Due to Ionizing Radiation[a]

Origin	Number of cases per year[b]	Number of cases per 10,000 years[b]
High-level radioactive waste disposal[c] (Proposed EPA standards)	up to 0.1	up to 1,000
Uranium mill tailings[d]:		
Unprotected*	3	30,000*
Protected (covered, etc.)	0.03	300*
Indoor air pollution:		
Residential exposure[e]	1,000 to 20,000	10,000,000 to 200,000,000*
Residential weatherization (added cases)[e] (Nero estimate)	250 to 5,000	2,500,000 to 50,000,000*
Residential weatherization (added cases)[f]	10,000 to 20,000	100,000,000 to 200,000,000*
Background radiation[g]	3,000 to 4,000	30,000,000 to 40,000,000
Cancer deaths (U.S.)[h] (all causes)	430,000	NA

[a] These numbers are all calculated on the same basis using a linear non-threshold dose response model. The linear non-threshold model involves a high degree of speculation, and the resulting values have little merit as absolute indicators of the numbers of biological effects that may occur. It has been used here to provide a framework within which relative risks from various radiation exposure situations can be compared.

[b] Assuming constant U.S. population and culture—numbers with (*) are extrapolated from annual values.

[c] EPA proposed rule 40 CFR Part 191 (December 1982) number per 100,000 tonne high-level radioactive waste repository.

[d] NRC, October 1980. "Uranium Mill Licensing Requirements: Final Rules," *Federal Register*, 45, No. 194, 65521-65538. Radon inhalation exposures.

[e] Nero, A. V., "Indoor Radiation Exposures From ^{222}Rn and Its Daughters: A View of the Issue," *Health Physics*, *45*, No. 2 (August 1983), 277-288.

[f] EPA Report EPA 520/4-78-013 (revised printing, July 1979).

[g] NAS/NRC, The Effects on Populations of Exposure to Low Level of Ionizing Radiation, November 1972, 1972 BEIR Report.

[h] American Cancer Society, Cancer Facts and Figures—1982, 1981.

* Does not include health effects from water pathways.

SOURCE: High-Level Radioactive Waste Disposal Subcommittee, Science Advisory Board, U.S. Environmental Protection Agency, "Report on the Review of Proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191)," January 1984, table A, pp. 12-13.

Table 3-2.—Projected Population Risks From High-Level Waste Disposal: EPA Reference Cases

	Projected health effects over 10,000 years						
Repository type	Routine release	Faulting	Drilling number (No hit)	Drilling number (Hit)	Breccia pipe	Volcano; meteorite	Total
Granite	10	+	750	+	—	+	760
Bedded salt	0	+	180	8	+	+	190
Basalt	1,400	3	3,000	2	—	+	4,400

Number = "No hit" means the drill does not hit solid waste but only repository water, while "hit" indicates the drill does hit solid waste.

+ = Less than 1 projected fatal cancer.

— = Not applicable.

SOURCE: U.S. Environmental Protection Agency, *Draft Environmental Impact Statement for 40 CFR 191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste*, EPA 520/1-82-025, December 1982, p. 205.

ground radiation. (Further analysis of the difference between high-level waste and spent fuel is found in the discussion of reprocessing below.) It should be noted, however, that these figures show that direct use of contaminated ground water that has not been diluted in a large volume of surface water could lead to doses to some individuals that are well above background levels.[31]

The acceptability of such expected effects is a value judgment, rather than a technical determination, and is the responsibility of the Environmental Protection Agency. EPA has proposed that the amounts of certain critical radionuclides that can be released from a repository in the first 10,000 years after emplacement be limited to specified levels that are calculated to produce no more than about 1,000 deaths (for a 100,000-tonne repository) during that period. The proposed limits are shown

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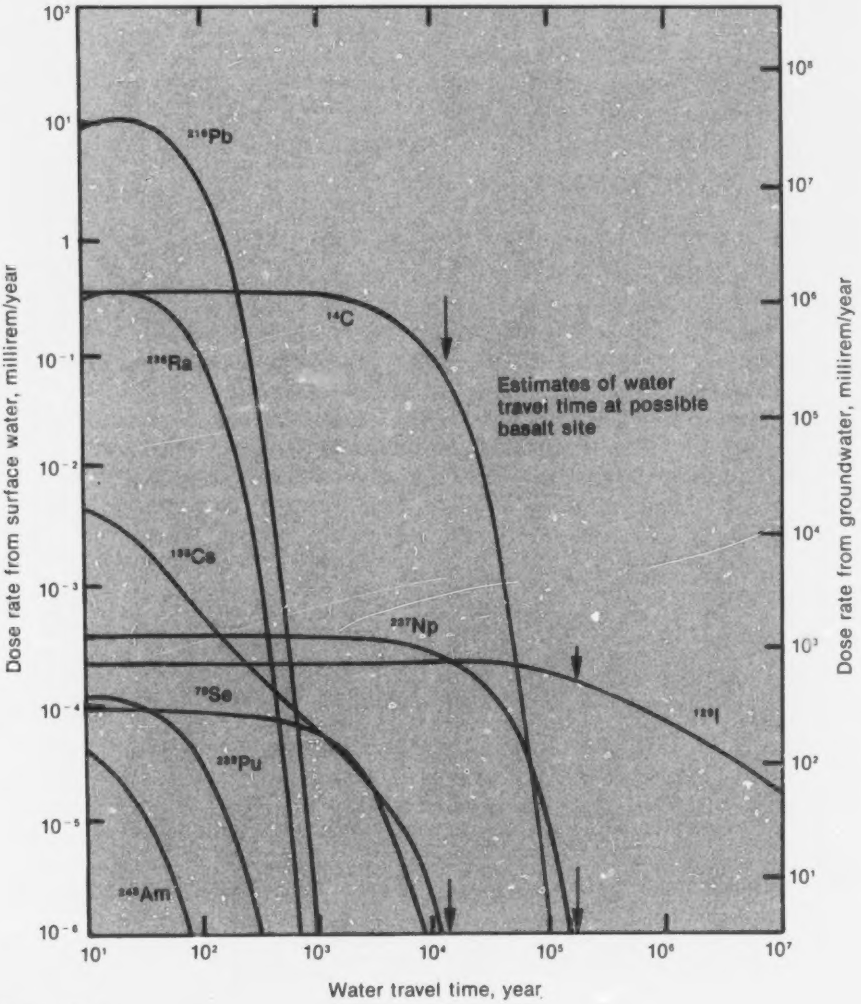
[31] EPA cites similar conclusions. EPA, *DEIS on 40 CFR 191*, p. 106.

Figure 3-3.—Individual Radiation Dose as a Function of Water Travel Time From a Repository in Basalt Containing 100,000 Tonnes of Unreprocessed Spent Uranium Fuel



Assumptions:

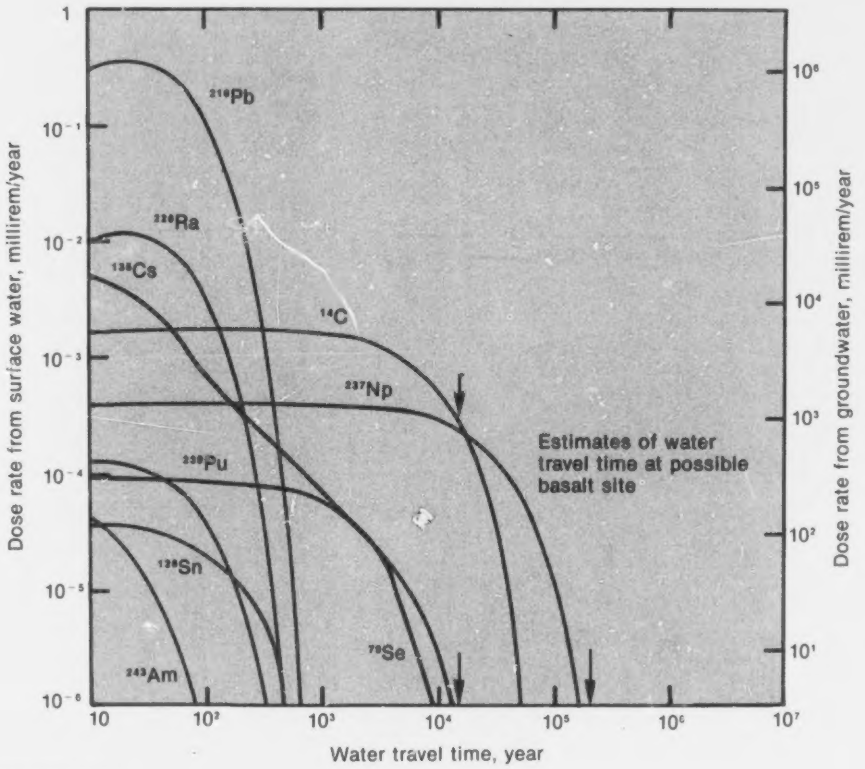
Dissolution rates = 10^{-4}/yr for C, Cs, and I. All other radionuclides dissolve at a rate determined by their own solubility rather than the rate of dissolution of the waste form.

River flow = 1.1×10^{11} m^3/yr

Groundwater flow = 3.2×10^4 m^3/yr

SOURCE: Adapted from National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, DC: National Academy Press, 1983).

Figure 3-4.—Individual Radiation Dose as a Function of Water Travel Time From a Repository in Basalt Containing Reprocessing Waste From 100,000 Tonnes of Spent Uranium Fuel



Assumptions:

Dissolution rates = 10^{-4}/yr for Cs. All other radionuclides dissolve at a rate determined by their own solubility rather than the rate of dissolution of the waste form.

River flow ≈ 1.1×10^{11} m^3/yr

Groundwater flow = 3.2×10^{4} m^3/yr

SOURCE: Adapted from National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, DC: National Academy Press, 1983).

in table 3-3. The NRC performance requirements for geologic repositories are summarized in appendix D.

It should be noted that there are disagreements in the technical community about the philosophical approaches reflected in both EPA's proposed standards and NRC's final regulations. The issues in dispute include whether to base the safety standards on what is theoretically achievable by a well engineered and sited repository, or on an independently determined standard of acceptable risk; whether to state the standard in the form of limits for the amounts of radionuclides that can be released by a repository over a fixed period, or in terms of acceptable levels of radiation exposure to, or health effects in, exposed populations or individuals; and whether to set performance standards for individual components of a repository system (such as the waste package), or only for the system as a whole.[32]

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[32] A discussion and critique of the NRC regulations and proposed EPA standards is found in National Research Council, *Isolation System*, ch. 8. Suggestions for revisions of the proposed EPA standards are found in the "Report on the Review of Proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR191)" by the High-Level Radioactive Waste Disposal Subcommittee of the Science Advisory Board of the U.S. Environmental Protection Agency, January 1984. This group suggested that the release limits be ten times higher than proposed by EPA.

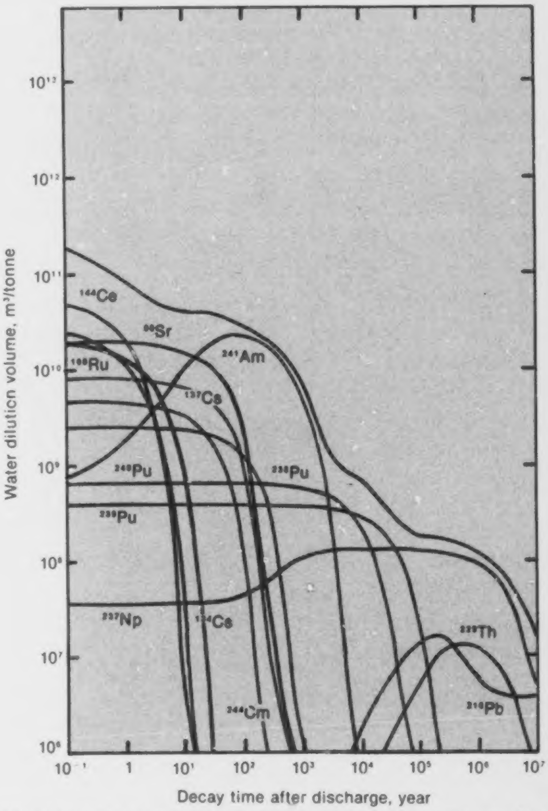
Table 3-3.—EPA Proposed Release Limits for Containment Requirements (cumulative releases to the accessible environment for 10,000 years after disposal)

Radionuclide	Release limit (curies per 1,000 tonnes)
Americium-241	10
Americium-243	4
Carbon-14	200
Cesium-135	2,000
Cesium-137	500
Neptunium-237	20
Plutonium-238	400
Plutonium-239	100
Plutonium-240	100
Plutonium-242	100
Radium-226	3
Strontium-90	80
Technetium-99	10,000
Tin-126	80
Any other alpha-emitting radionuclide	10
Any other radionuclide which does not emit alpha particles	500

SOURCE: U.S. Environmental Protection Agency.

Figures 3-3 and 3-4 can also provide perspective on the point emphasized in chapter 2: that simple toxicity indices, such as water dilution volumes, are a misleading measure of the hazard posed by radioactive waste. Figure 3-5 shows the contribution made to the toxicity of spent fuel by each of the most significant radionuclides. Comparing that figure with figures 3-3 and 3-4 shows that, with the exception of neptunium-237 (Np^{237}) in the very long term, *none of the radionuclides that are the principal contributors to the predicted dose from waste in a repository are major contributors to the total toxicity of the waste.* The major contributors to the toxicity are in general expected to decay before they can reach the environment. Some, like strontium-90 and cesium-137, have short half-lives so that they will decay to negligible levels even within relatively short water travel times. Others with longer half-lives, like americium and plutonium, are expected to be retarded severely by chemical reactions with the surrounding rock so that they will move much more slowly than the ground water and thus will take a very long time to escape, even if the water travel time is not long compared to the half-life.

Figure 3-5.—Water Dilution Volume of PWR Spent Fuel



SOURCE: National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, DC: National Academy Press, 1983).

Cost

DOE estimates that the cost of designing, constructing, operating, and decommissioning a geologic repository having a capacity of 70,000 tonnes of spent fuel will range from $5 billion to $7 billion (in 1983 dollars), depending on a range of factors, including the nature of the site and medium.[33] Two repositories of this capacity should accommodate all of the radioactive waste generated over the 40-year expected operating lifetime of the nuclear powerplants in existence or under construction in the United States. The actual number required will depend on a number of factors, including the physical capacity of the sites that are found, the repository designs that are finally adopted, the size of the nuclear power system that must be served, and the relative amounts of spent fuel and solidified high-level waste that are disposed of.[34]

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[33] U.S. Department of Energy, *Mission Plan for the Civilian Radioactive Waste Management Program*, draft, DOE/RW-0005 (Washington, D.C.: April 1984), vol. II, table 10-6, p. 10-14.

Other Disposal Technologies[35]

Subseabed Disposal

Next to mined geologic repositories, the disposal concept that has been the focus of the most study is subseabed disposal. Subseabed disposal involves the emplacement of high-level radioactive waste beneath the ocean floor within the thick (200 to 500 feet [ft]) clay sediments that cover large expanses of the relatively deep (3 to 4 miles) midoceanic regions. These flat-lying, homogeneous sediments could provide sufficient disposal for all the high-level radioactive waste produced worldwide. Because these remote, deep-ocean areas lack significant levels of mineral and biological resources, the likelihood of human intrusion is very low. The midoceanic regions are among the most stable and predictable geologic environments on Earth. Moreover, the ocean itself provides an additional isolating barrier between the sediment surface and land-based ecosystems. On the other hand, subseabed disposal presents added safety risks from ocean transportation accidents. Although waste retrieval would be possible with existing technology, its cost would probably be prohibitive for all but safety reasons.

Additional work is needed before the scientific feasibility of seabed disposal can be determined. For example, further research is needed to determine whether the waste canister and the sediments will adequately contain the wastes, and models to predict the physical and biological transport of radionuclides in the ocean must be developed.[36]

In its relatively small subseabed research program (funded at $6 million in fiscal year 1982), DOE is studying not only the potential migration of radioactive material within the oceanic sediments and ecosystem, but also transport, emplacement, and isolation systems. Large regions of the ocean have been screened and many areas explored in more detail; several prospective sites have been selected for in situ testing. Resolving technical questions about the impacts from the international dumping of low-level radioactive waste onto the ocean floor may be required before the emplacement of high-level radioactive waste could be initiated.

With subseabed disposal, the domestic political difficulties associated with siting land-based mined repositories might be replaced with similar difficulties in siting the shipping facilities.[37] In addition, significant national and international legal problems might require resolution before this concept could be implemented. The Ocean Dumping Act (Public Law 92-532) can be interpreted to ban subseabed disposal of high-level waste. At the international level, the 1972 London Dumping Convention prohibits high-level radioactive waste from being dumped into the oceans or placed on the surface of the seabed. However, since subseabed disposal involves emplacing the waste beneath the sediment surface, the legal status of this option relative to existing international laws and the ongoing Law of the Sea negotiations is presently ill-defined, and there is currently no official U.S. position on the matter.[38] Implementation of this disposal alternative would probably require an international agreement as well as specific U.S. congressional action.

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[34] DOE analysis that took such factors into account concluded that a maximum of five or six repositories would be needed for a nuclear power system that reaches a maximum of 250 GW_e of installed generating capacity. DOE, *FEIS*, table 7.3.10, p. 7.29.

[35] The conclusions about these other disposal technologies are drawn primarily from three sources in which these alternatives are analyzed: DOE, *FEIS*, 1980; IRG, op. cit.; and U.S. Department of Energy, *Statement of Position of the United States Department of Energy in the Matter of the Proposed Rulemaking on the Storage and Disposal of Nuclear Waste*, DOE/NE-0007 (Washington, D.C.: Apr. 15, 1980). For brevity, specific references to these sources will be omitted.

[36] Robert D. Klett, *Subseabed Disposal Program Annual Report: Systems, October 1981 Through September 1982*, SAND83-1835 (Albuquerque, N. Mex.: Sandia National Laboratories, February 1984), p. 8.

[37] A full discussion of the domestic and international issues in subseabed disposal is found in Edward Miles, Kai N. Lee, and Elaine Carlin, *Sub-Seabed Disposal of High-Level Nuclear Waste: An Assessment of Policy Issues for the United States* (Seattle, Wash.: University of Washington Institute for Marine Studies, July 21, 1982).

[38] K. R. Hinga and D. R. Anderson, "The Institutional Program for an International Subseabed Repository," in U.S. Department of Energy, *Proceedings of the 1982 National Waste Terminal Storage Program Information Meeting* (Washington, D.C.: December 1982), pp. 68-70. See also Seabed Programs Division, *The Seabed Disposal Program: 1983 Status Report*, SAND 83-1387 (Albuquerque, N. Mex.: Sandia National Laboratories, October 1983).

To enhance the level of international cooperation in the evaluation of subseabed disposal, an international seabed working group has been created with a membership that currently includes the United States, the United Kingdom, France, Canada, Japan, the Netherlands, the Federal Republic of Germany, Switzerland, and the Commission of European Communities. In addition, Italy and Belgium have participated as observers in the cooperative R&D efforts of this group. This high level of international interest and cooperation indicates that *subseabed disposal is widely regarded as the most promising alternative disposal technology to mined geologic repositories*. In addition to the potential value of subseabed disposal for the United States, it may be useful to maintain a viable seabed R&D program for both low- and high-level radioactive waste to ensure the safe and equitable use of the seabed by the international community and to provide an alternative for those countries that cannot dispose of radioactive waste on land.

Deep Holes

Deep-hole disposal involves the disposal of waste-filled canisters at the bottom of holes 12 to 15 inches in diameter, drilled to a depth of 20,000 to 50,000 ft, well below the maximum depth of ground water movement. At these extreme depths, the potential for disturbance by natural surface forces or human intrusion or for transport by ground water to the biosphere would theoretically be minimized. However, significant uncertainties remain about the character of the hydrogeologic environment and about waste/rock interactions at these depths. Simply determining the suitability of alternative sites at such depths is extremely difficult.

This concept requires larger holes and heavier drilling equipment than are currently available, although these technical requirements are probably manageable by extensions of existing technology. The difficulty of keeping holes of this depth open may complicate waste emplacement. Moreover, the logistics of deploying a full-scale, deep-hole system may be significant; as many as 2,000 holes may be required if the commercial spent fuel from existing reactors and those under construction are to be accommodated. This number could conceivably be reduced by a factor of 10 for high-level waste from reprocessing operations if the heat produced by the waste did not cause significant problems. Each hole would probably require 3 to 6 years to drill. Once emplaced, it might be practically impossible to retrieve the waste and extremely difficult to verify the degree of isolation obtained.

Rock Melting

Rock melting involves pumping newly generated high-level liquid waste into a conventionally mined cavity at depths of 5,000 to 6,000 ft. The high levels of heat produced by the waste would theoretically melt the surrounding rock within several decades; the resultant resolidification of the rock/waste mixture into a presumably insoluble matrix would require many hundreds of years. Rock melting can only be used for disposing of newly generated high-level waste from the reprocessing of unaged spent fuel. Therefore, any high-level waste generated from reprocessing older spent fuel, as well as the transuranic waste from reprocessing, will have to be disposed of in another manner.

Since the rock-melting concept has not been studied to any great extent, it contains numerous and potentially significant uncertainties about waste handling and emplacement techniques, about the physical and chemical interaction of the melted material with the host rock, and about the potential migration of the radioactive material after emplacement. Retrieval of the waste is not possible with rock melting, and verification of isolation after emplacement, even over the short term, may be difficult. The number of rock-melting disposal sites, of course, would depend on the size of the cavities used. For example, a mined cavity 80 ft in diameter would be capable of containing the high-level liquid waste generated by reprocessing 50,000 tonnes of spent fuel. Rock melting could offer substantial cost advantages over the development of mined repositories because the mining activity for rock melting is considerably less than that for the development of mined repositories.

Well Injection

From an operational point of view, a relatively simple means of permanently isolating liquid high-level waste from reprocessing would be to pump it to depths of 500 to 5,000 ft into a well in a suitable hydrogeological environment at or near a reprocessing plant. Two such injection wells would probably be required for a reprocessing plant with a capacity of 2,000 tonnes/year (yr). Retrieval of wastes injected into deep wells would be limited, if not entirely impractical.

In grout injection, certain suitable rock formations, such as shale, at depths of 300 to 500 ft would first be hydrofractured by injecting a fluid under high pressure down a borehole. A mixture of liquid radioactive waste and self-hardening grout, such as cement, would then be injected into the fractured rock, leaving the waste in a relatively immobile and essentially irretrievable form. Hydrofracturing has been used at the Oak Ridge National Laboratory to dispose of 1.8 million gallons of liquid defense waste at a single well site, and monitoring has shown no indication of any postinjection migration of radioactive material away from the grout sheets. Approximately 40 grout injection wells would probably be required at a reprocessing plant having a capacity of 2,000 tonnes/yr.

Well-injection techniques have already been used to dispose of various types of industrial wastes. In fact, there are approximately 300 industrial waste-disposal wells that have been or are in operation in the United States. However, at this time, there are only limited field data on the long-term containment of these wastes. In addition, deep-well injection of any waste is prohibited in 12 States and discouraged in another 7. Nine other States have regulations controlling its use.

Ice Sheets

The ice sheets of Greenland and Antarctica, where ice thickness reaches several thousand feet, could conceivably provide a remote, low-temperature environment for containing radioactive waste. The waste could be allowed to melt down through several thousand feet of ice to the bedrock under the ice, to be suspended in the ice to a depth of a few hundred feet from cables anchored at the ice surface, or to be stored in surface facilities that would gradually sink toward the bedrock under the weight of naturally accumulating snow and ice. In the first and second cases, refreezing of the water above the waste as it melts through the ice would theoretically seal the emplacement hole. Cases two and three could theoretically provide a certain degree of retrievability for a few hundred years. However, once inside the ice sheet, the waste would migrate slowly (over an estimated period of tens to hundreds of thousands of years) with the ice toward the perimeter of the ice sheet where the ice breaks off as icebergs.

Although there are apparent advantages to this disposal concept, an international group of glaciologists recommended in 1974 that the Antarctic ice sheet not be used for waste disposal because of the many uncertainties about its general nature, evolution, and behavior, as well as the unknown relationship between ice sheet dynamics and as yet unpredictable climatic changes. The principal uncertainties concern the stability of the ice masses for very long periods (10,000 years or more) and the possibility that the waste, once in contact with the basement rock, would be broken up mechanically and escape along unknown pathways. As in subseabed disposal, international negotiations and the signing of treaties would be necessary before this concept could be implemented.

Space

Placing encapsulated radioactive waste into orbit around the Sun would eliminate the waste irretrievably from the Earth itself. According to concepts studied by DOE, spent fuel would first be reprocessed and the high-level liquid waste from reprocessing would be solidified into an acceptable waste form. After transporting the solidified waste to the launch site, an upgraded space shuttle would carry the waste into orbit around the Earth. An orbital transfer vehicle would then be used to carry the waste from the shuttle to the position of solar orbit between Earth and Venus. (Shooting the waste directly into the Sun would require too much fuel to be practical.) After the orbital transfer vehicle had been recovered, the shuttle would return to Earth for reuse.

Although conceptually attractive and probably technically feasible, space disposal is not considered an immediate and viable disposal option because of undeveloped technology, the large number of space shuttle launches required (a thousand or more per year for spent fuel or 4 to 6 dozen per year for high-level waste), and the uncertain, yet potentially serious, consequences of an accident during launch that might release significant quantities of radioactive waste into the atmosphere. Since space disposal appears to be economically feasible only for selected long-lived elements, or perhaps for the total amount of high-level reprocessed waste, reprocessing of commercial spent fuel would be required first. An alternative disposal system would then be needed for the remaining radioactive waste not destined for space.

Assuming adequate funding and the resolution of existing technical problems, this disposal concept could possibly be ready for use by the year 2000. However, resolution of numerous and potentially significant political and international issues as well as a large number of legal complexities could lengthen the time needed to implement this disposal option.

Transmutation

Transmutation is a treatment (not disposal) technique that theoretically could be used to convert (transmute) the long-lived radionuclides in radioactive waste (in particular, the transuranic radionuclides such as Np^{237}) into stable or short-lived radioisotopes by neutron bombardment in nuclear reactors. The process requires reprocessing spent fuel, with the addition of a step that would separate (partition) the long-lived radionuclides from the liquid high-level waste so that they could be incorporated into new fuel rods and recycled through nuclear reactors. Although this process should theoretically reduce the long-term hazards associated with the waste, recent work has indicated that the process may result in an increased radiation hazard during the short term because of the additional complex operations that are involved, along with a very small decrease in long-term hazards.[39] In fact, partitioning and transmutation involve such an increase in operational complexity that the process can be seen as a new fuel cycle rather than simply as an incremental modification of the reprocessing fuel cycle.[40]

Since only 5 to 7 percent of the recycled elements are transmuted while the fuel is in the reactor, numerous recycles would be required to transmute all the long-lived radioisotopes. Although specially designed reactors could conceivably increase the rate of the transmutation process, most of these advanced technologies would require 20 to 30 years to develop. Transmutation would substantially increase both the handling requirements and the volume of secondary wastes generated, thereby more than doubling the total costs of waste management. In addition, since fission products have to be disposed of after transmutation, the need for other waste disposal technologies would not be eliminated.

Comparison of Disposal Alternatives

The general attractiveness of a particular disposal option as a basis for the Federal waste management program is affected by the following factors: 1) the relative degree of safety it offers, 2) the type of waste it can accommodate, 3) its provision for retrieving waste, 4) the potential international complications from developing or deploying the option, and 5) cost.

Technology Status

Disposal in mined geologic repositories has received far more attention on a worldwide basis, and hence is far more advanced in development, than any of the other disposal technologies. As discussed above, subseabed disposal is also now the focus of an international research effort, and its scientific and engineering feasibility could conceivably be tested by the end of this century. The other technologies have received far less attention, and it would require considerable effort to develop the same level of understanding about their advantages and disadvantages that now exists about mined repositories and subseabed disposal.

Relative Degree of Safety

It is difficult to compare different waste emplacement and disposal options in terms of safety, not only because some have not been analyzed in much detail, but also because such comparisons involve a complicated balancing between differences in long-term isolation on the one hand and offsetting differences in near-term operational risks on the other. In general, the more remote the environment into which the waste is emplaced (e.g., outer space), the greater the isolation that can be achieved. At the same time, remote environments involve increased difficulty and risks during emplacement (e.g., the risk of accidental reentry of waste into the atmosphere in space disposal) and greater difficulty of monitoring the waste to detect unanticipated problems (and of taking corrective actions such as retrieval) if such problems arise.

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[39] A. G. Croff, J. O. Blomeke, and B. C. Finney, *Actinide Partitioning-Transmutation Program Final Report. I. Overall Assessment*, ORNL-5566 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, June 1980).

[40] Ibid.

An additional safety consideration arises in the case of those disposal alternatives, such as rock melting, that require that spent fuel be reprocessed. If reprocessing were undertaken specifically to allow use of such an alternative, the additional operational risks and worker exposures resulting from reprocessing would have to be balanced against any long-term safety advantages afforded by the disposal technology.

Type of Waste

Because of significant uncertainties about the future of commercial reprocessing in this country and the large quantities of spent fuel expected to be generated by the reactors that now are operating or are under construction, it appears possible that at least some spent fuel might be discarded directly as waste. Thus, the ability to accommodate spent fuel as well as high-level waste from reprocessing could be an important consideration in choosing a disposal system. Only some disposal technologies—e.g., mined repositories, deep holes, subseabed, and space—would have that ability, and in some of those cases (in particular, space disposal), technical considerations could make their use for spent fuel impracticable.

Ability to Retrieve Waste

Because of the uncertainties about the degree of long-term isolation that any disposal system would provide, it may be desirable to maintain some ability to recover the waste after emplacement if the development of scientific understanding shows that the risks were greater than anticipated at the time of emplacement. In fact, EPA's proposed criteria for high-level waste disposal would require that removal of most of the waste be possible for a reasonable period after disposal.[41]

Because disposal systems rely heavily on natural barriers to prevent radioactive waste from being released into the environment, these same natural barriers make human access to, and retrieval of, the waste quite difficult after final emplacement. In some cases, retrieval could be practically impossible. Thus, for example, the proposed EPA retrievability requirements might preclude use of such technologies as deep-hole emplacement and rock melting.

In addition to such safety considerations, retrievability might also be desirable in order to keep the option of reprocessing spent fuel. The mined geologic repository appears to be the only disposal technology that could allow economic retrieval of spent fuel after emplacement, although this may only be possible before the repository has been backfilled and sealed.

Potential International Complications

Legal and institutional difficulties at the international level could be encountered in any attempt to use space, subseabed, or ice sheet disposal. However, the extent to which these problems could constrain the development of these disposal alternatives is uncertain. The potential for such complications could make some technologies relatively unattractive as a choice for the primary focus of the United States' radioactive waste-management program.

Cost

Preliminary cost estimates by DOE indicate that mined geologic disposal and subseabed disposal could be the least expensive options (on the order of 0.1¢/kilowatt-hour [kWh] of nuclear-generated electricity), while deep-hole disposal could cost several times as much (around 0.3¢/kWh).[42] Estimates of the costs of other options are too incomplete to permit a similar calculation of the unit cost of disposal. All such estimates are uncertain at this point, in part because the final safety standards and regulations for high-level waste disposal have not been adopted yet, and thus the final performance requirements for disposal systems are not certain. In addition, the cost of those disposal options that require reprocessing is unknown because it is not clear if the cost of such reprocessing would be offset completely by the sale of the recovered uranium and plutonium or if part or all of the cost would have to be included as part of the cost of waste disposal. Nonetheless, since these estimated costs (excluding reprocessing costs) are a small fraction (a few percent) of the typical current new construction cost of generating nuclear electricity with a new facility,[43] it appears unlikely that the ultimate disposal costs would significantly affect the economics of nuclear power even if they are increased substantially over current estimates.

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[41] EPA, *DEIS on 40 CFR 191*, p. 127.

[42] DOE, *FEIS*, table 6.2.7, p. 6.192.

Conclusions

Based on analyses of the above factors, *the development of mined repositories in the continental United States appears to provide the most immediately available disposal technology suitable for both spent fuel and high-level waste from reprocessing that could be developed by the United States.* Despite potential international problems, subseabed disposal presently provides the most promising alternative to the use of mined repositories. If commercial reprocessing is ever developed fully, it may be advantageous to consider other options, such as deep holes or rock melting, for disposing of the high-level waste from reprocessing. However, even if all spent fuel were reprocessed and the high-level waste were disposed of using another disposal alternative, there would still be other waste products generated by the reprocessing operation (in particular, large volumes of transuranic-contaminated waste) that may have to be disposed of in mined repositories.

Although the development of mined repositories could be deferred until more information about alternative disposal technologies is available, it is not clear what benefits would be gained by such deferral.[44] In fact, *there is considerable consensus within the technical community that the development of mined repositories should not be deferred, and the Nuclear Waste Policy Act of 1982 (NWPA) made a commitment in law to operation of a geologic repository by 1998* (see ch. 5).

There is disagreement about the desirability of developing other disposal options as insurance against the remote possibility that mined repositories cannot be developed because of unforeseen technical or institutional problems. The annual budgets for the commercial waste management program have increased gradually from $1.7 million in fiscal year 1972 to approximately $317 million in fiscal year 1982. Of this latter amount, approximately 97 percent is devoted to the development of mined repositories. Subseabed, deep-hole, and space disposal options may be investigated further as technologies to back up or complement the development of mined repositories, but are not now planned for full development. NWPA also provides for accelerated investigations of such alternative disposal technologies.

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[43] Ibid., pp. 7.50-7.51.

[44] See discussion in issue 1, app. B.

WASTE STORAGE

Unlike disposal technologies, storage technologies are designed to allow easy retrieval of the emplaced material. Thus, they cannot rely as heavily on remoteness and impenetrable natural barriers to prevent accidental releases and human intrusion, but instead must use engineered features and continued human control. In effect, the price of easy retrievability is the need for continued care, maintenance, and monitoring of the storage facility.

As noted in chapter 2, large amounts of new storage capacity will be needed at least for the next several decades simply to hold the spent fuel generated by commercial reactors until adequate disposal or reprocessing capacity becomes available. Storage for considerably longer periods may also be used either to maintain access to spent fuel for possible future reprocessing or to allow waste (either spent fuel or high-level waste) to cool before emplacing it in a repository for permanent disposal. Some also view permanent storage as an acceptable way, in itself, to provide final isolation of the waste. (For further discussion, see issue 1 in app. B.) Thus, storage technology may be required to function for periods ranging from 10 years or less to 100 years or more.

Discussions about storage technology are sometimes clouded by the use of different terms (e.g., "away-from-reactor" [AFR] and "monitored, retrievable storage" [MRS]) that have been associated with particular policy debates (see issue 4 in app. B). For example, the term "AFR" came into general use in the debate about whether the Federal Government should provide centralized (thus, away-from-reactor) storage facilities to enable the Government to accept spent fuel from utilities during a relatively short interim period until a geologic repository would be available, which was assumed to be as quickly as possible. In contrast, the term "MRS" was introduced in the context of a debate about whether the Federal Government should provide storage facilities designed for spent fuel and high-level waste that could provide an alternative to geologic repositories for an extended period—perhaps 100 years or longer. However, some also see an MRS facility as providing a cushion against relatively short slippages in the geologic repository program. In that event, there would be little practical difference between the two concepts.

In general, a system that can store spent fuel satisfactorily can also be designed to store high-level waste from reprocessing. Therefore, although the discussion of storage in this section focuses on spent fuel storage, for which there is the greatest immediate need, it also pertains to storage of solidified high-level waste from reprocessing.

Interim Storage Technology

Water-Filled Basins

Practically all the existing commercial spent fuel is currently stored at reactor sites in water-filled basins that were originally designed to store freshly discharged spent fuel for a short period (6 months) until it could be reprocessed. Such basins are an effective way to provide the high level of radiation shielding and thermal cooling needed during such initial storage periods.

Photo credit: Department of Energy

Spent fuel storage basin at a commercial nuclear powerplant

Since reactor basins were originally not intended to provide storage for an accumulating inventory of spent fuel, their potential capacity was not maximized. The capacity of those reactor basins, or of new independent water basins, may be increased in two ways: reracking and rod consolidation.

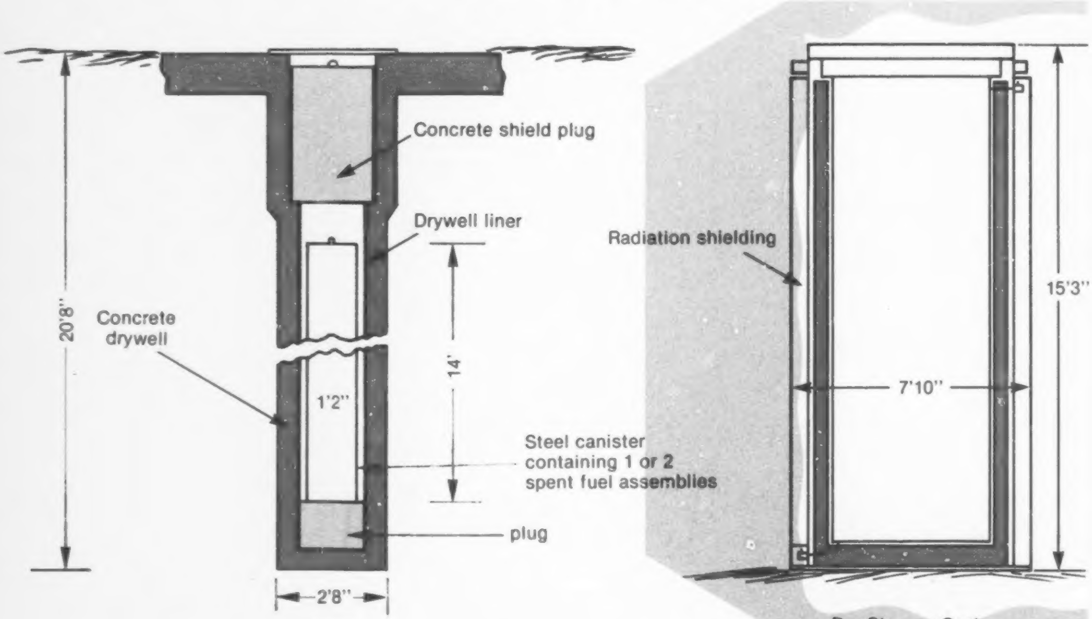
Reracking allows closer spacing of spent fuel elements by replacing the original, inefficient, but relatively inexpensive aluminum storage racks that hold the spent fuel assemblies with more expensive racks made of other materials. Because reracking in existing basins is by far the least expensive and easiest way to provide additional storage capacity, utilities have been doing it as needed since the mid-1970's. By reracking, utilities can increase the capacity of many reactor basins that were designed originally to hold up to 4 to 5 annual spent fuel discharges by up to 10 additional annual discharges. DOE assumes that utilities will exploit the potential for reracking to the maximum extent possible before considering other storage options.

Rod consolidation involves disassembling spent fuel elements and packing the individual fuel rods more closely together in steel storage canisters. This technology could allow the capacity of existing storage basins to be nearly doubled in some instances (subject to structural limitations on the ability of the basin to withstand the additional load) at a cost comparable to reracking. Although large-scale rod consolidation has not been demonstrated yet, such demonstrations are planned for the next few years. If successfully demonstrated, this method could reduce the need for additional storage facilities to some extent by the end of the decade, and substantially by the end of the century. However, rod consolidation will probably not be usable at every reactor because of structural limitations on the total weight of spent fuel that can be placed in some water basins. Rod consolidation could also be used to increase the storage capacity of the dry storage technologies discussed next.

Dry Storage

Several concepts for dry storage of spent fuel are under consideration for new storage facilities (see fig. 3-6). Since dry storage appears to be suited for storage over long and uncertain periods, it has been selected over water basins in each major Federal analysis of extended storage options.[45] Most of the following dry storage concepts require sealing spent-

Figure 3-6.—Dry Storage Concepts for Spent Fuel



Drywell

Each drywell would hold a steel canister containing about 0.5 tonnes of spent fuel (1 or 2 fuel assemblies depending upon the type of reactor).

Dry Storage Cask

Each cask would contain about 10 tonnes of spent fuel (24 to 52 assemblies).

If licensed, dry storage technologies like these may provide a relatively inexpensive, flexible alternative to water-filled basins for in-fuel elements in steel canisters prior to emplacement:

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[45] U.S. Atomic Energy Commission, *Preliminary Draft Environmental Statement, Retrievable Surface Storage Facility* (Richland, Wash.: November 1974); U.S. Department of Energy, *The Monitored Retrievable Storage Concept: A Review of Its Status and Analysis of Its Impact on the Waste Management System*, DOE/NE 0019 (Washington, D.C.: December 1981); D. E. Rasmussen, *Comparison of Cask and Drywell Storage Concepts for a Monitored Retrievable Storage/Interim Storage System*, PNL-4450 (Richland, Wash.: Battelle Memorial Institute, Pacific Northwest Laboratory, December 1982.

- Air-cooled vault—a large concrete structure using natural air convection for cooling.
- Concrete surface silo—a concrete cylinder sitting vertically on the ground.
- Casks—large metal casks (which may be designed to be used for transportation as well) sitting vertically in warehouselike sheds.
- Surface drywell (dry caisson)—a steel- and concrete-lined hole that will hold one or several spent fuel elements.
- Tunnel drywell storage—drywells sunk in the floor of subterranean tunnels.
- Tunnel rack storage—movable racks placed in tunnels inside a mountain.

Comparison of Interim Storage Technologies

Status of Technology Development

Because the water-filled basin is the only storage technology now in use in licensed facilities, it has been considered until recently the only viable option for new facilities in the next decade. Estimates of the time required to design, construct, and license an independent basin facility range from about 7 years at a licensed reactor site to 9 years at a new site.

However, recent studies indicate that some alternative dry-storage technologies may be available for use before 1990.[46] A cast iron cask of West German design and a cask of U.S. design are being used by DOE and the Tennessee Valley Authority (TVA) for tests and a licensed demonstration expected to be completed in 1987. It is possible that such cask technology could be licensed on a generic basis, i.e., approved for use at any licensed reactor site, thereby reducing the lead time required for a decision by a utility to use the technology. Both drywells and surface silos are being tested currently by DOE at the Nevada Test Site.

Because of the significant potential advantages of these technologies in safety, cost, time, and speed of implementation, it seems important to determine their licensability and actual cost quickly, particularly for at-reactor use. NWPA includes measures to accomplish this. If no major licensing problems are encountered, cask or drywell facilities could be constructed at reactor sites in about 4 years.[47] Additional research, development, and demonstration of dry storage will be required to develop a full-scale system that can reliably receive, package, and emplace waste at the very high annual rates (2,000 tonnes/yr) that would be involved in a large, centralized storage facility.[48] There is, however, no apparent technical reason why this cannot be done.

The cask and the surface drywell are currently considered to be leading candidates for new storage capacity both at existing reactor sites[49] and at centralized facilities for interim or extended storage.[50] A DOE study estimates that a centralized dry storage facility using either casks or drywells could be designed, sited, and constructed in about 11 years.[51] Other dry-storage technologies, such as the tunnel-rack system, have received less study to date.[52]

NRC has adopted regulations for licensing independent spent fuel storage facilities using wet or dry technologies for periods up to 20 years.[53] Since these regulations were designed for interim storage, it is not clear whether additional issues might be raised in the case of extended storage (for periods up to 100 years or longer).[54] If extended storage facilities were intended to be used for terminal isolation, for example, more sophisticated engineered features such as waste packages might be required to control releases that might occur if institutional control were lost or abandoned. If existing regulations had to be modified for licensing facilities for extended storage, additional time could be required to construct such a facility.

Safety

There appear to be no fundamental questions about the technical ability to design, construct, and operate interim spent fuel storage facilities to meet applicable radiation protection standards as long as continuing surveillance and maintenance of the facilities is provided. Safe storage in water basins has already been demonstrated, and it appears likely that equally safe, perhaps safer, storage can be provided with dry-storage technologies.[55] While there may be disagreements about the safety of particular system designs (e.g., certain methods for expanding the capacity of existing storage basins at reactors), these disagreements do not challenge the conclusion that safe storage is technically feasible.

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[46] E. R. Johnson Associates, Inc., *A Preliminary Assessment of Alternative Dry Storage Methods for the Storage of Commercial Spent Nuclear Fuel, JAI-180,* DOE/ET/47929-1 (Reston, Va.: November 1981).

[47] Ibid.

[48] Rasmussen, op. cit., p. 6.46.

[49] E. R. Johnson Associates, Inc., op. cit.

[50] Rasmussen, op. cit.

[51] DOE, *The Monitored Retrievable Storage Concept.*

[52] Ibid.

[53] 10 CFR, pt. 72.

[54] DOE, *Monitored Retrievable Storage Concept,* p. 2-14.

Water basins are simple structures that have been used successfully for the storage of radioactive materials, including spent fuel, for 30 years. The engineering practices and procedures involved in their design and construction are well established. Experience shows that spent fuel can be stored under water safely without significant deterioration of the fuel elements for periods of at least 20 years and perhaps considerably longer, particularly if the fuel assemblies are sealed in stainless steel canisters to contain leakage.

Although there has been much less experience with dry storage than with water basins, dry technologies may have potential safety advantages. First, unlike water-filled basins, they do not rely on an active cooling system. Furthermore, the heavily shielded containers required in most dry technologies would provide a massive physical barrier against accidents (e.g., airplane crashes) or sabotage and would limit the effects of such an event to a few fuel elements. However, longer aging (about 5 years) is required before spent fuel can be placed into dry storage, and the fuel, once encapsulated, becomes hotter than in a water basin. While there has been relatively little experience with dry storage of spent fuel from light-water reactors (LWRs), NRC regulations for independent interim storage facilities contemplate licensing dry-storage facilities.[56]

The conclusion that high-level radioactive waste can be stored safely is based on the assumption that the storage facilities will continue to be controlled and maintained.[57] *However, extended (or permanent) storage raises a safety issue that does not arise with interim storage: the possibility that institutional control of the storage facility would be terminated before the waste decays to innocuous levels.* This situation could result either from the loss of society's ability to care for the facility (through war or social regression) or, perhaps more likely, from carelessness or declining concern by later generations, leading to a decision not to continue to bear the costs of maintenance despite the potential long-term consequences.

No detailed quantitative analysis yet compares the safety of extended storage to that of direct disposal as a means of providing final isolation.[58] Existing analyses of the safety of storage facilities deal only with the releases that might occur during a period of temporary storage under continuous human control. No analyses of accidents that could cause releases from a storage facility over a very long period are comparable in thoroughness to the many studies of the possible ways that wastes could escape from a mined repository. In particular, there are no studies of the consequences of premature termination of institutional control, the "accident" in a storage facility that is most comparable to a physical breach of containment in a mined repository.

Flexibility

Water basins and dry vaults are fixed structures with physical limits to their storage capacity. While they can be designed to allow modular expansion, such expansion is usually economical only for large increments of capacity. In addition, they require relatively long lead times for construction and licensing—about 7 years for a basin or dry vault at a reactor site, compared to as little as 3½ years for a cask storage facility.[59] In contrast, the dry technologies that use separate, freestanding containers for individual fuel elements (shipping casks, drywells, and silos) all allow expansion of capacity in very small increments and on relatively short notice once the required packaging facilities are available. As a result, they appear better able to meet the uncertain storage requirements that now face utilities.

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[55] M. S. Plesset, "ACRS (Advisory Comittee on Reactor Safeguards) Comments on Proposed Rulemaking on the Storage and Disposal of Nuclear Waste," Letter (Dec. 10, 1980) to John F Ahern, U.S. Nuclear Regulatory Commission. Quoted in DOE, *Monitored Retrievable Storage Concept*. See also U.S. Nuclear Regulatory Commission, *Waste Confidence Decision*.

[56] 10 CFR, pt. 72.

[57] Plesset, op. cit.

[58] A brief qualitative comparison is found in the discussion of issue 1 in app. B.

[59] E. R. Johnson Associates, Inc., op. cit., table 7-1, p. 7-3.

Cost

The total undiscounted costs of constructing and operating a 1,000-tonne storage facility at a reactor site are estimated to range from $82 million (for casks using fuel consolidated in the reactor basin) to $260 million (for unconsolidated fuel in a dry vault).[60] The comparable undiscounted totals for a centralized dry-storage facility with a 48,000-tonne capacity range from $2.4 billion (for surface drywells and tunnel racks) to $5.3 billion (for tunnel drywells).[61] A comparison of capital and operating costs for a range of at-reactor spent fuel storage options is shown in table 3-4.

The wide range of technical and financial assumptions used in the available studies of storage technologies precludes any simple comparison of the cost per tonne of using each of the storage technologies at different locations. Examination of the available DOE studies, however, leads to several general conclusions:

1. *For both at-reactor and away-from-reactor use, those technologies providing relatively large, fixed capacities (water basins or dry vaults) appear to be more expensive per tonne of storage than do the dry technologies that allow expansion in annual modules (drywell, silos, and casks).*[62] The principal reason is that the modular dry technologies have a lower initial capital cost, and their remaining costs can be spread out over time as additional containers are built. Deferring much of the total costs in this way reduces the discounted cost of storage and thus makes the expandable technologies even more attractive financially as capital costs increase. It also lowers the financial risk involved in making a large investment in fixed storage capacity when the total amount of storage needed is uncertain.

Table 3-4.—Comparison of Capital and Annual Operating Costs of At-Reactor Storage Options
($/kilogram of uranium—operating costs in parentheses below capital costs)

	Facility capacity (tonnes)		
Storage option	500	1,000	2,000
Cask (5-tonne capacity)	118 (1.3)	109 (0.7)	103 (0.4)
Vault (fuel canned)	100 (1.9)	87 (1.6)	81 (1.5)
Cask (10-tonne capacity)	80 (0.3)	75 (0.2)	73 (0.2)
BWR reracking (stainless steel to borated stainless steel)	63 (1.1)	61 (1.1)	60 (1.1)
Pool	97 (4.9)	59 (3.0)	42 (2.0)
Silo	70 (4.9)	59 (3.0)	42 (2.0)
Vault (fuel not canned)	67 (2.1)	48 (1.5)	39 (1.2)
Drywell	53 (0.9)	41 (0.7)	35 (0.6)
PWR reracking (stainless steel to borated stainless steel)	39 (0.5)	38 (0.5)	38 (0.5)
Rod consolidation within existing pool[a]	40	—	—
PWR reracking (low density to stainless steel)	25 (0.4)	25 (0.4)	25 (0.4)
BWR reracking (low density to borated stainless steel)	22 (1.0)	22 (1.0)	22 (1.0)
BWR reracking (low density to borate stainless steel)	20 (1.0)	20 (1.0)	20 (1.0)
PWR reracking (low density to borated stainless steel)	18 (0.4)	18 (0.4)	18 (0.4)
Double tiering[b]	—	—	—

[a] No operating cost data available.
[b] No cost data, but reracking costs represent lower limits.

SOURCE: Electric Power Research Institute, *Cost Comparisons for On-site Spent-Fuel Options*, EPRI NP-3380, May 1984, tables 12-1, 12-2.

2. *The least expensive way to provide storage using casks or drywells appears to be to locate the storage facility at the site of a reactor, reprocessing plant, or geologic repository where existing staff and equipment can be used for packaging and handling spent fuel (or solidified high-level waste) for storage.* A major part of the capital cost for a modular dry-storage facility at an independent site is for the equipment and facilities needed for handling and packaging the spent fuel prior to insertion in

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[60] Ibid., table 8-1, p. 8-3. Amounts are in 1981 dollars.

[61] DOE, *The Monitored Retrievable Storage Concept*, table 2-3, p. 2-20. Amounts are in 1981 dollars.

[62] E. R. Johnson Associates, Inc., op. cit., p. 2; DOE, *FEIS*, vol. 2, app. A, table A-8, p. A-100.

individual storage units.[63] A recent study of centralized extended storage using casks and drywells concluded that substantial savings would be achieved if the cost of handling facilities (several hundred million dollars) could be avoided by locating the storage facility at a repository or reprocessing plant that would have such facilities in any case, rather than at an independent site.[64] Since it may also be possible to use modular dry storage at reactors with only relatively minor modifications to existing facilities, decentralized storage at reactors may also prove to be less expensive than centralized storage at a stand-alone facility. However, there is as yet no consistent comparison of centralized v. decentralized storage using dry-storage technologies and using the same financial assumptions for both cases.

3. *Once a spent fuel element has been stored at an interim storage facility, it may be less expensive to leave it there indefinitely than to remove it and transport it elsewhere.* For example, DOE estimates that the annual cost of caretaker operations at a 48,000-tonne dry-storage facility would be at most about $2.7 million, or about $56/tonne/yr.[65] In contrast, annual retrieval operations would range from $4.1 million to $10.7 million, while transportation to another site would cost at least $15,500/tonne—nearly 300 times the annual caretaking cost.[66] Thus, an important consideration in planning the full-scale operation of a waste disposal system will be how rapidly to draw down the backlogs of spent fuel that will already have been placed in storage by the time disposal begins. This point is discussed further below and in chapter 6.

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[63] DOE, *The Monitored Retrievable Storage Concept*; Rasmussen, op. cit.

[64] Rasmussen, op. cit.

[65] DOE, *The Monitored Retrievable Storage Concept*, table 2-1, p. 2-18.

[66] Ibid., table 2-4, p. 2-22.

WASTE TRANSPORTATION

Spent fuel is transported using heavily shielded containers called shipping casks. At present three types of casks are used:[67]

- Legal weight truck casks weigh about 23 tons and hold one pressurized water reactor (PWR) fuel assembly or two boiling water reactor (BWR) fuel assemblies. There are 11 such casks in the United States.
- Overweight truck casks weigh about 35 tons and hold 3 PWR fuel assemblies or 7 BWR fuel assemblies. They are restricted in movement because of their weight. There is one such cask under construction.
- Rail casks weigh from 64 to 90 tons and hold from 7 to 10 PWR fuel assemblies or from 18 to 24 BWR fuel assemblies. There are six rail casks in the United States.

Solidified high-level waste from reprocessing would also be shipped in similar heavily shielded casks, although such casks are still in the conceptual design stage.

The combined capacity of the existing truck and rail casks is 28 tonnes. DOE estimates that this capacity would be adequate for shipments through 1988, even if all additional storage capacity beyond existing basins were provided at a centralized storage facility, and that it would be possible for the industry to meet the demand for additional casks after that time.[68]

Future casks may be somewhat different from those now in operation. New casks may be able to carry up to twice as much fuel as current ones if designed to carry only fuel that is at least 5 years old.[69] Such fuel has about one-tenth the output of heat and radiation as 150-day-old spent fuel, for which existing casks were designed. Since it appears unlikely that spent fuel less than 5 (or even 10) years old would be moved for the next few decades,[70] there will be strong financial incentives to develop and use casks that hold more spent fuel than current designs. In addition, transportation in the future may be done in casks that are designed for storage,[71] and perhaps for disposal,[72] as well.

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[67] These data are drawn from U.S. Department of Energy, *Spent Fuel Storage Fact Book*, DOE/NE-0005, April 1980, p. 54. OTA is currently conducting a more detailed examination of container testing, safety standards, and risks associated with transportation as part of its ongoing assessment of *Transportation of Hazardous Materials*. Information systems and regulatory and institutional issues relating to the safe transport of nuclear waste and other hazardous materials will also be studied as part of this assessment.

[68] Ibid., p. 39.

Safety

Standards

Transportation of highly radioactive materials is governed by NRC and U.S. Department of Transportation (DOT) regulations requiring that shipping casks be designed to limit radiation exposure to bystanders during normal operations (10 millirems/hour at 6 ft from the cask) and to prevent release of radioactive materials from the cask even in severe accidents. Casks must be designed to withstand a sequence of hypothetical tests without releasing more than a specified small amount of radioactive material.[73] (It should be noted that the ability of a cask design to pass these tests is assessed by analytical methods rather than by actual performance of the tests on sample casks.) These design criteria, which are intended to encompass a range of very severe accident conditions, include sequential exposure to:

- a 30-ft drop onto a flat, unyielding surface with the cask oriented to cause the greatest damage;
- a 40-inch drop onto a 6-inch-diameter steel pin mounted on an unyielding surface; and
- a 30-minute, all-engulfing thermal environment (fire) radiating at 1,475° F.

The same requirements have been adopted by the International Atomic Energy Agency and are in general use worldwide.

Questions have been raised about the adequacy of these requirements (and of existing casks designed to meet them) in view of the conditions that might be encountered in realistic accidents. For example, it is noted that some actual fires are hotter than 1,475° F and some accidents involve impacts at higher velocities than those involved in the drop test. In this regard, the regulatory test conditions are engineering criteria that provide a well-defined basis for designing and analyzing casks. They are intended to create stresses on the cask at least as great as those produced by a wide range of extreme accident conditions that could actually be encountered.[74] Thus, while an individual aspect of a specific test (e.g., drop height or temperature) might be exceeded in real accidents, other test aspects are more severe than could be encountered in the real world. For example, objects in the real world are not completely unyielding; if struck by a transportation cask, they would absorb some of the energy of the cask. Similarly, actual fires are not likely to surround all surfaces of a cask completely, as specified in the regulatory test, and a fire that surrounds only part of a cask would have to be hotter and/or longer than the regulatory fire to provide the same heat input to the cask.

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[69] Ibid., p. 39. See also J. A. Bucholz, *A Summary Report on Optimized Designs for Shipping Casks Containing 2-, 3-, 5-, 7-, or 10-Year-Old PWR Spent Fuel*, ORNL/CSD/TM-150 (Oak Ridge Tenn.: Oak Ridge National Laboratory, April 1983), table 4a, p. 25. The maximum capacity of an optimal rail cask design for 10-year-old spent fuel is 21 PWR assemblies, compared to existing rail casks holding 12 PWR assemblies.

[70] Analyses generally assume that the oldest fuel would be reprocessed or disposed of first. DOE analysis suggests that even if reprocessing began at large scale by 1990, the youngest spent fuel being reprocessed in 2020 would still be at least 10 years old. U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/NE-0017/2, September 1983, table 1.4., p. 20.

[71] D. E. Rasmussen, op. cit., p. 6.32.

[72] Westinghouse Electric Corp., *Engineered Waste Package Conceptual Design, Defense High-Level Waste (Form 1), Commercial High-Level Waste (Form 1), and Spent Fuel (Form 2), Disposal in Salt*, AESD-TME-3131 (Pittsburgh, Pa.: September 1982).

[73] 49 CFR 173.398 (c). Transport regulations are 10 CFR 71 and 10 CFR 73.

[74] For example, it has been estimated that the regulatory 30-ft drop onto an unyielding surface would be more severe than about 99.9 percent of all accidents, while the 30-minute fire requirement is longer in duration than 99.8 percent of actual fires involved in rail or truck accidents. See Edwin L. Wilmot, *Transportation Accident Scenarios for Commercial Spent Fuel*, SAND80-2124 (Albuquerque, N. Mex.: Sandia National Laboratories, February 1981), pp. 47-48. Analysis of the 1982 Caldecott Tunnel fire near San Francisco, in which a gasoline tanker burned in a highway tunnel, concluded that the fire could have produced a heat input into a shipping cask ranging from a minimum of one-fourth to a maximum of twice the heat input from the standard regulatory fire conditions. D. W. Larson, R. T. Reese, and E. L. Wilmot, "The Caldecott Tunnel Fire Thermal Environments, Regulatory Considerations and Probabilities" (Albuquerque, N. Mex.: Sandia National Laboratories, undated), table 2.

Experiments that have been performed using shipping casks show how the regulatory tests can be more severe than actual accident conditions that, at first glance, appear to exceed the requirements. For example, a cask would only reach a speed of about 30 miles per hour (mph) in the regulatory 30-ft drop test. Yet in an experiment in which a truck carrying a spent fuel cask was driven head-on into a reinforced concrete target at 61 mph, the actual forces experienced by the cask were less than those that would result from the drop test.[75] In 1984, the British Central Electricity Generating Board performed the 30-ft drop test on an actual 48-tonne steel spent-fuel shipping cask, with no reported damage to the cask.[76]

Similarly, experiments in which spent fuel shipping casks were exposed to fires that were hotter and/or longer than the standard fire specified in the regulations showed that the actual environments produced by those fires were comparable to, or less severe than, the regulatory test requirements.[77] Additional tests to determine the actual properties of various fire environments are now underway at Sandia National Laboratories under DOT sponsorship. Such tests could be quite valuable in resolving questions about the relationship between existing regulatory requirements and actual accident conditions.

In 1981 NRC determined that no immediate changes in current regulations were needed to improve safety. At the same time, it initiated a "Modal Study of Transportation Safety" designed to:

- collect data on severe accident conditions and their relative frequency;
- devise package tests that simulate those accident conditions;
- analyze and/or test packages under severe accident conditions and assess their performance; and
- using this information, evaluate further the adequacy of present standards to protect against potential high consequence accidents and develop possible changes to NRC standards, if appropriate.[78]

This study is expected to be completed by the end of 1985.

While OTA did not attempt in this study to evaluate any particular technology designs or regulations, its review of the debate about transportation safety did not reveal any fundamental technical challenges to the conclusion that shipping casks can be designed to prevent significant radioactive releases in realistic accident conditions.[79] At the same time, it is clear that the central role of shipping cask integrity in providing transportation safety places considerable importance on ensuring that great care is taken in the manufacture, testing, use, and maintenance of casks. A transportation panel of the National Academy of Sciences' Committee on Radioactive Waste Management concluded that:

> . . . the transportation of radioactive materials is not a major factor in the total hazards associated with the nuclear power system. However, this conclusion is supportable only if the highest standards of care are applied in all aspects of waste preparation and transportation.[80]

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[75] Michael Huerta and Richard H. Yoshimura, *A Crash Test of a Nuclear Spent Fuel Cask and Truck Transport System*, SAND77-0419 (Albuquerque, N.Mex.: Sandia Laboratories, January 1978), p. 16. It should be noted that this test was designed to assess the accuracy of analytical techniques for predicting the response of a cask to a collision, rather than to evaluate regulatory standards or cask designs.

[76] *The Energy Daily*, Mar. 8, 1984, p. 4.

[77] Tests involving a 30-minute, 1,200° C torch fire led to cask heating that was substantially less than would be produced by the regulatory fire. Manuel G. Vigil, Amado A. Trujillo, and H. Richard Yoshimura, "Measured Thermal Response of Full-Scale Spent Fuel Cask to a Torch Environment," *Nuclear Technology*, vol. 61, June 1983, pp. 514-520. Analysis of exposure of a shipping cask in a railcar to a 2-hour petroleum fuel fire concluded that the amount of heat input to the cask was about equivalent to that resulting from the 30-minute regulatory test fire. J. E. Hamann et al., "Modelling of Pool Fire Environments Using Experimental Results of a Two-Hour Test of a Railcar/Cask System," *Proceedings of the 6th International Symposium, Packaging and Transportation of Radioactive Materials*, Nov. 10-14, 1983, pp. 1081-1088.

[78] NRC comment in preface to P. Eggers, *Severe Rail and Truck Accidents: Toward a Definition of Bounding Environments for Transportation Packages*, NUREG/CR-3499 (Washington, D.C.: U.S. Nuclear Regulatory Commission, October 1983), p. iii.

[79] Recent critiques of radioactive waste transportation have focused on the adequacy of existing cask designs and regulatory requirements and have suggested that suitable casks could be designed. Marvin Resnikoff, *The Next Nuclear Gamble* (New York: Council on Economic Priorities, 1983), pp. 20-21. See also Robert M. Jefferson, "Transporting Spent Reactor Fuel: Allegations and Responses," SAND82-2778 (Albuquerque, N. Mex.: Sandia National Laboratories, March 1983); and Robert M. Jefferson et al., "Analysis of Recent Council on Economic Priorities Newsletter" SAND82-1250 (Albuquerque, N. Mex.: Sandia National Laboratories, May 1982).

[80] Report of the Panel on Transportation to the Committee on Radioactive Waste Management, August 1974, cited in letter from John C. Frye, Chairman of the Committee on Radioactive Waste Management, to Dr. Robert C. Seamans, Jr., Administrator of the U.S. Energy Research and Development Administration, Feb. 12, 1975.

Thus, confidence in the safety of waste transportation will depend on confidence that shipping casks will in fact be designed, constructed, and operated according to packaging regulations. *Past experience with lax enforcement of packaging regulations concerning low-level waste shipments,[81] and recent criticisms of the adequacy of enforcement of regulations concerning spent fuel shipping casks,[82] suggest that enforcement could become an issue of increasing concern as shipments of spent fuel increase.* A recent review of the regulatory structure of high-level radioactive waste transportation concluded that it is inadequate in several respects and recommended a careful evaluation of Federal regulation of highway transport of radioactive waste.[83]

Risk Analyses

Analyses of the risks of transporting spent fuel (or solidified high-level waste) in casks designed to existing regulatory standards generally suggest that the radiological risks to the public from accidental releases of radioactive materials during transportation would be very small in comparison to the health effects from normal operation of the fuel cycle.[84] For example, a recent study evaluated the costs and impacts of shipping 72,000 tonnes of spent fuel (or the wastes from reprocessing that amount of fuel) to five possible repository sites over a 26-year period. This study concludes that for a repository at Hanford, Wash., there would be, at most, 78 nonradiological fatalities and 16 long-term cancer fatalities if the material were all moved by truck, or about 6 nonradiological fatalities and 36 long-term cancers if it were moved by rail.[85] In comparison, EPA's analysis of waste disposal, discussed earlier in this chapter, concluded that a repository containing 100,000 tonnes of spent fuel could cause 1,000 or more deaths in a 10,000-year period after disposal.

These risk studies also indicate that even a worst-case situation, involving a major breach of a cask as a result of an accident or deliberate sabotage, would not lead to catastrophic effects, but rather might result in at most 10 to 15 deaths from cancer in the long term. For example, an NRC study of the effects of releases from transportation of radioactive materials in urban areas concluded that the maximum consequences of accidental penetration of a spent fuel cask would be one cancer death in the long term, with no early fatalities.[86] A DOE study of transportation by truck that examined accident environments much more severe than those specified in the regulatory tests (e.g., a collision producing a large breach in the cask and failure of all of the fuel rods, followed by a 2-hour, 1,850° F fire) concluded that the maximum number of resulting deaths would be about 10, and that the probability of an accident of that magnitude would be less than 1 in 1 million per year.[87]

The NRC study of transportation of radioactive materials in cities also examined the possible effects of deliberate sabotage involving the use of explosives to penetrate a shipping cask, to pulverize part of the contained material, and to disperse that material into the environment. Using conservative assumptions about the amount of material that could be released by sabotage, this study calculated that such an attack on a truck cask loaded with 6-month-old spent fuel in New York City could cause from tens to hundreds of cancer fatalites, while an attack on a rail cask could produce hundreds to thousands of cancer fatalities, depending on the precise time and location of the attack and the weather conditions.[88] (While there would be no early deaths from radiation, the explosion itself could be expected to cause about 10 deaths.[89]) However, a more recent assessment, based on experiments using explosives to determine how much material actually might escape from a cask as a result of sabotage, concluded that, at most, 14 cancer deaths might result in the long term, with 4 deaths expected.[90]

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[81] U.S. Department of Transportation (DOT) and U.S. Department of Energy, *National Energy Transportation Study*, July 1980, p. 118.

[82] Resnikoff, op. cit., ch. V.

[83] National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal* (Washington, D.C.: National Academy Press, 1984), pp. 123-128. See also Paul F. Rothberg, "Nuclear Materials Transportation: Safety Concerns, Governmental Regulations and Activities, and Options to Improve Federal Programs," Congressional Research Service Report No. 84-45 SPR, Mar. 15, 1984.

[84] U.S. Nuclear Regulatory Commission, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170, vol. 1, December 1977, p. 5-52.

[85] Edwin L. Wilmot et al., *A Preliminary Analysis of the Costs and Risk of Transporting Nuclear Waste to Potential Candidate Commercial Repository Sites*, SAND83-0867 (Albuquerque, N. Mex.: Sandia National Laboratories, June 1983), table 4, p. 12.

[86] Sandia National Laboratories, *Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment*, NUREG/CR-0743, SAND79-0369 (Washington, D.C.: U.S. Nuclear Regulatory Commission, July 1980), table 3-11, p. 66.

[87] Pacific Northwest Laboratory, *An Assessment of the Risk of Transporting Spent Nuclear Fuel by Truck*, PNL-2588 (Seattle, Wash.: Battelle Memorial Institute Pacific Northwest Laboratory, November 1978), fig. 2.1, p. 2-4.

[88] Sandia National Laboratories, op. cit., table 5-20, p. 131.

[89] Ibid., table 5-20, p. 131.

While the risk of fatalities from releases of radioactive material during spent fuel transportation is calculated to be very low, the economic impacts from a substantial release could be very high. These impacts are estimated to be roughly comparable for a worst-case accident and deliberate sabotage—from $2 billion to $3 billion for an incident in a city.[91] The major costs of both are almost entirely attributable to the denial of use of the contaminated area while cleanup occurs; once an area has been contaminated to the level that nonuse is necessary, futher contamination does not appear to increase the cost.[92] By way of comparison, accidents involving shipments of other common hazardous materials (e.g., gasoline, anhydrous ammonia, or chlorine) that are less well protected and more likely to escape if a shipping tank ruptures may be more likely to cause significant numbers of deaths than accidents involving shipments of spent fuel.[93] However, the costs of a worst-case accident with radioactive waste could be higher because of the cost of cleaning up the resulting radioactive contamination, a problem that does not occur with most other hazardous materials.[94]

The adequacy of the worst-case accident analyses that have been performed to date has been questioned on the grounds that substantial uncertainties remain about the severity of "real-world" accidents and about the amount of radioactive material that might be released.[95] On the other side, some argue that the analyses deal adequately with the uncertainties by using conservative assumptions that tend to overestimate the consequences.[96]

Transportation risk analyses have not been subject to the same degree of independent peer review as have studies of the risks of geologic disposal. Such a review, taking into account the results of the experiments and studies that have been performed in the last 5 years, could help resolve some of the disagreements about transportation safety and the adequacy of the existing regulatory structure.

Conclusions

OTA did not undertake a detailed evaluation of risks associated with any stage of waste management—storage, transportation, or disposal. However, a brief review of the areas of disagreement between transportation risk analyses suggests that many of the arguments are based on the assumption that very young spent fuel (150 days old or less) is being transported—the assumption that was usually made when rapid reprocessing of all spent fuel was anticipated. Such fuel generates so much heat from radioactive decay that loss of the coolant used to keep the temperature inside the cask to acceptable levels can lead to rapid overheating of the fuel, release of radioactive materials from the solid fuel pellets into the cask cavity, and subsequent escape of those materials into the environment. It should be noted that the analyses leading to the conclusion that the maximum consequences of a worst-case accident would be 10 to 15 cancer deaths take such overheating into account. Others, however, argue that much higher temperatures (and thus much greater release of radioactivity) could result if fuel were shipped that has been cooled after discharge from the reactor less than the 120 days required by NRC regulations—or if a cask were exposed to a fire that is longer and/or hotter than the fire specified in the regulatory test.[97]

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[90] Robert P. Sandoval et al., *An Assessment of the Safety of Spent Fuel Transportation in Urban Environs*, SAND82-2365 (Albuquerque, N. Mex.: Sandia National Laboratories, June 1983). This analysis was based on experiments with fresh fuel. Similar results, in terms of the estimates of the amount of material that would escape, were obtained in experiments using spent fuel. E. W. Schmidt et al., *Final Report on Shipping Cask Sabotage Source Term Investigation*, Battelle Columbus Laboratories, NUREG/CR-2472 (Washington, D.C.: U.S. Nuclear Regulatory Commission, October 1982).

[91] Sandia National Laboratories, op. cit. The maximum direct economic impact for an accident is $2 billion (table 3-11, p. 66) while the maximum for sabotage is $3 billion (table 5-17, p. 128).

[92] Ibid., p. 126.

[93] The probability of an accident leading to one or more deaths is estimated to be about 2.2 in 100,000 per year for shipment of spent fuel in trucks. See Pacific Northwest Laboratory, op. cit., p. 11-3. No such accident has ever occurred. In comparison, DOT reports a number of accidents involving one or more deaths associated with the shipment of gasoline and anhydrous ammonia in 1977 alone. DOT and DOE, *National Energy Transportation Study*, table 6-2, p. 108.

[94] Ibid. This report shows that although there were 1,500 incidents involving the transportation of gasoline, leading to 21 deaths and 47 injuries, the total damage came to $6,981,317.

[95] Resnikoff, op. cit.

[96] A Federal court has reviewed NRC's risk analyses and has concluded that they are adequate as a basis for transportation regulations. *The City of New York and the State of New York v. The United States Department of Transportation, Et Al. and Commonwealth Edison Company, Et Al.*, United States Court of Appeals for the Second Circuit, Docket Nos. 82-6094, 82-6200, decided Aug. 10, 1983. This decision overturned a lower court decision invalidating in part the DOT Reg. HM-164 governing the highway transportation of large quantities of radioactive materials.

These arguments could be rendered moot, or at least greatly reduced in force, by the fact that the only spent fuel likely to be shipped in the foreseeable future will be at least 5 years old, and more likely more than 10 years old.[98] As noted above, the heat output of 5-year-old fuel is about one-tenth that of 150-day-old fuel. As a result, the maximum temperature of the fuel resulting from self-heating will be much lower than is possible with young spent fuel. This has several important implications for analysis of the risk of transporting spent fuel.

First, the consequences of a breach of a cask or failure of its seals would be substantially reduced. Shipment of young spent fuel requires a coolant (generally water) to keep the temperature of the fuel at an acceptable level. Existing studies show that loss of the coolant through a breach in the cask or a failed seal or valve is a principal contributor to total risk because it leads to rapid overheating of young spent fuel. Because the heat output of older spent fuel is so much lower, no coolant is required in the shipping cask to keep the temperature down. In fact, old spent fuel is now shipped without coolant in existing shipping casks,[99] and casks designed especially for transporting older fuel will probably not use a special coolant.[100] As a result, accidents that could breach the cask or cause its seals to fail would not lead to a rapid increase of the fuel temperature, as would be the case if the coolant escaped from a cask carrying 150-day-old fuel.

Because self-heating from radioactive decay is much less of a problem with old spent fuel, fire appears to be the only potential mechanism for heating spent fuel to the high temperatures some have suggested could lead to major releases. One study that argues that very large releases of radioactive materials could occur in a worst-case accident bases this conclusion on the assumption that under certain circumstances the temperature of the fuel might reach as high as 2,000° F, exceeding the temperature at which the fuel cladding would deteriorate (about 1,688° F).[101] Analyses of currently licensed casks show that the hypothetical regulatory fire (30 minutes at 1,450° F) would lead to an average maximum fuel temperature of only about 1,000° F in 120- to 150-day-old spent fuel.[102] An analysis that considered fires more severe than the regulatory fire concluded that even a 2-hour, 1,850° F fire could produce a maximum temperature of about 1,600° F in 150-day-old spent fuel in a truck cask.[103] Furthermore, this analysis indicates that the major effect of a fire of that length and temperature would be to cause a loss of coolant from the cask, which in turn would lead to rapid overheating of the fuel. This self-heating, rather than the fire itself, would cause most of the sharp temperature increase.[104] This situation in turn implies that a substantially longer and/or hotter fire would be required to produce excessive heating in old spent fuel in a shipping cask, since decay heat from the fuel would play a much less important role. Analysis shows that the regulatory fire would produce a maximum temperature of 660° F in 5-year-old fuel in a rail cask designed for such older fuel. This is only 148° F higher than the normal operating temperature of 502° F. With 10-year-old fuel, the maximum temperature would be 559° F.[105]

These considerations suggest that the risks of transporting spent fuel could be substantially reduced if only older fuel were shipped. One study calculates that the risk from transporting spent fuel by truck in existing shipping casks could be reduced by a factor of about 6 if the fuel were cooled for 4 years before shipment.[106] As noted earlier, there could be strong economic incentives to ship older fuel in casks that have been optimized for that purpose. Designing the casks for fuel that is at least 10 years old would provide an additional margin of conservatism compared to 5-year-old fuel since, as noted, it would reduce the maximum temperature reached in the regulatory fire by about 100° F.

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[97] Resnikoff, op. cit., pp. 266-267.

[98] U.S. DOE, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, fig. C.2, p. 284, fig. C.3, p. 285.

[99] Jefferson et al., *Analysis of Recent Council on Economic Priorities Newsletter*, p. 19.

[100] Bucholz, op. cit., p. 7.

[101] See Resnikoff, op. cit., pp. 266-267.

[102] See Edwin L. Wilmont, *Transportation Accident Scenarios*, p. 17.

[103] See Pacific Northwest Laboratory, op. cit., pp. G-7—G-11.

[104] This study calculates that loss of coolant with no fire would lead to a maximum fuel temperature of 1,360° F (738° C). Addition of a 2-hour, 1,850° F fire increased that maximum to 1,598° F, an increment of 238° F. Pacific Northwest Laboratory, op. cit., app. G.

[105] Bucholz, op. cit., table 3, p. 22.

[106] Pacific Northwest Laboratory, op. cit., p. 11-3.

Cost

A truck cask for spent fuel shipment is estimated to cost about $700,000, while rail casks cost up to $3.9 million.[107] The total cost of shipping 1 tonne of spent fuel for a distance of 1,500 miles is estimated to be about $21,000; the cost of transporting the high-level waste from 1 tonne of spent fuel is estimated to be about $3,000.[108] Total transportation costs should represent less than 20 percent of the cost of waste management.[109] These costs can be reduced by using casks designed to ship larger quantities of older spent fuel and by using regional repository sites located to reduce transportation distances to the greatest extent possible.[110]

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[107] U.S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020, June 1983, table 3-9, p. 18.

[108] Ibid., table 3-8, p. 17.

[109] Ibid., tables A-1, A-2, A-3, A-4, pp. 42-45.

[110] K. D. Kirby et al., *Evaluation of the Regional Repository Concept for Nuclear Waste Disposal*, USDOE Office of Nuclear Waste Isolation Report ONWI-62 (Columbus, Ohio: 1979), pp. 183-186.

REPROCESSING

Status of Reprocessing

The commercial nuclear power system was envisioned originally to include reprocessing of all spent fuel and reuse of the recovered uranium and plutonium. However, while reprocessing and recycling can reduce the requirements for uranium ore, it will not be attractive commercially until the cost of the recovered material becomes competitive with the cost of fresh uranium. At present, nuclear reactors are being delayed or canceled, and no new orders are being placed because of uncertainties about the demand for electricity, the cost of reactors, and other factors.[111] As a result, it appears that there may be an excess capacity in the uranium mining industry and uranium enrichment worldwide through the 1990's,[112] a situation that bodes ill for the commercial attractiveness of reprocessing in the next few decades. At present, there appears to be no private interest in undertaking reprocessing in the United States.[113] Moreover, there is growing agreement within the technical community that large-scale commercial reprocessing will not be attractive economically except as part of a nuclear power system including breeder reactors,[114] and breeder reactors themselves may not become economically competitive with LWRs for decades.[115]

Reprocessing of commercial spent fuel is under way currently in several countries, including France and the United Kingdom, which are contemplating eventual use of breeder reactors. The quickest path for initiating the large-scale reprocessing of commercial spent fuel in the United States appears to be the completion of the Allied General Nuclear Services (AGNS) facility at Barnwell, S.C. However, the owners of that facility have recently abandoned the project, and completion and operation of the plant would therefore probably require Federal intervention.[116] At present, the AGNS chemical separation facility, with a design capacity of 1,500 tonnes/yr, and the spent fuel receiving and storage station have been completed. Full-scale operation of the plant would require construction of additional major facilities for conversion of recovered plutonium into solid plutonium dioxide (PuO_2) and solidification and storage of high-level waste from reprocessing. A number of regulatory issues must also be resolved before a reprocessing facility could be completed and operated. Licensing and operation of the AGNS facility or any new reprocessing plant would require a generic proceeding dealing with reprocessing and plutonium recycle and a licensing proceeding to resolve site- and design-specific issues associated with the particular facility.[117]

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[111] U.S. Congress, Office of Technology Assessment, *Nuclear Power in an Age of Uncertainty*, February 1984.

[112] Congressional Budget Office, *Uranium Enrichment: Investment Options for the Long Term*, October 1983. See also "Uranium Shortage Turns to Glut," *Science*, vol. 225, Aug. 3, 1984, p. 484.

[113] "Jilted Reprocessor Vents Spleen," *The Energy Daily*, Apr. 16, 1984, p. 2.

[114] The International Nuclear Fuel Cycle Evaluation (INFCE) concluded that recycle of plutonium in LWR's would be an economically marginal proposition and that most countries now planning to use plutonium are planning to use breeder reactors. INFCE, *Summary Volume* (Vienna: International Atomic Energy Agency, 1980), p. 145.

[115] In the United States, the experimental Clinch River breeder reactor project has been canceled, and European breeder programs are experiencing increasing delays. See "Europe's Fast Breeders Move to a Slow Track," *Science*, vol. 218, Dec. 10, 1982, pp. 1094-1097.

[116] "Jilted Reprocessor," op. cit.

The AGNS facility could probably be completed, licensed, and operating in about 10 years.[118] Estimates of the cost for constructing the additional required facilities at AGNS range from $580 million to $950 million.[119] A new reprocessing facility with the same annual capacity is estimated to cost from $1 billion to $1.6 billion, assuming a predictable schedule is maintained.[120] Since there is no experience with much of the required technology at commercial scale in the United States, and since there are substantial remaining regulatory uncertainties (e.g., waste solidification criteria), these schedule and cost estimates should be viewed with caution.[121]

Reprocessing for Waste Management

Because it was generally assumed until the mid-1970's that spent fuel would be reprocessed to recover the usable uranium and plutonium, plans for waste management focused on solidified high-level waste from the reprocessing operation. However, the increasing uncertainty about the economic incentive for reprocessing has focused attention on the option of direct disposal of spent fuel. In this context, some have suggested that reprocessing might be desirable as a waste management step, in view of its potential advantages over disposing of unreprocessed spent fuel—for example, 1) removing the plutonium and uranium produces a more benign waste product with lower volume, toxicity, and long-term heat output than spent fuel, and 2) reprocessing allows the use of potentially better disposal technologies (e.g., less soluble waste forms or alternative approaches, such as isotope partition and transmutation).

Despite such potential advantages, major studies that have considered reprocessing in the context of waste management have concluded that reprocessing of commercial spent fuel is not required for safe waste isolation. Mined repositories can be designed for the safe isolation of either spent fuel or high-level waste from reprocessing, or both.[122] Moreover, reprocessing—which generates additional radioactive waste streams and involves operational risks of its own—does not appear to offer advantages that are sufficient to justify its use for waste management reasons alone.[123] Thus, while large-scale reprocessing of commercial spent fuel would have significant implications for waste management, those implications would not be a major factor in the decision on whether to undertake such reprocessing. Instead, the decision to reprocess would depend on whether the recovery and recycling of unused fissionable material in the spent fuel is more attractive from an economic and energy policy point of view than using freshly mined uranium.[124]

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[117] U.S. Department of Energy, *Nuclear Proliferation and Civilian Nuclear Power: Report of the Nonproliferation Alternative Systems Assessment Program* (NASAP), vol. IV, DOE/NC-0001/4, June 1980, p. 184.

[118] Ibid., p. 184; International Energy Associates Limited (IEAL), *Study of the Potential Uses of the Barnwell Nuclear Fuel Plant (BNFP)*, IEAL-141, Mar. 25, 1980, fig. 4-13, p. 145.

[119] IEAL, op. cit., p. 137; DOE, *Nuclear Proliferation and Civilian Nuclear Power*, vol. IV, p. 185.

[120] DOE, *Nuclear Proliferation and Civilian Nuclear Power*, vol. IV, p. 185.

[121] IEAL, op. cit., p. 144.

[122] INFCE, *Summary Volume*, p. 21; APS, op. cit., p. S107; National Research Council, *Isolation System*, p. 11; and K. D. Closs and H. Geipel, “Some Preliminary Results of the FRG (Federal Republic of Germany) Alternative Fuel Cycle Evaluation,” presented at the International Meeting on Fuel Reprocessing and Waste Management, Jackson, Wyo., Aug. 26-29, 1984.

[123] INFCE, *Summary Volume*, p. 21: “Working Group 7 generally concluded, taking into account not only health and safety and environmental impacts but also the other assessment factors, that the difference in the impacts of waste management and disposal among the reference fuel cycles does not constitute a decisive factor in the choice among them. Employing technology assumed, the radioactive wastes from any of the fuel cycles studied can be managed and disposed of with a high degree of safety and without undue risk to man or the environment.” APS, op. cit., p. S112: “Although influencing details of repository design, none of the factors we have identified concerning waste management are of determining importance in the choice among fuel cycles.” Page S107: “In particular, arguments concerning . . . waste management are not important in deciding between recycle and non-recycle fuel cycle options.” While the National Research Council Waste Isolation System Panel concluded that adequate isolation could be provided for spent fuel as well as high-level waste, it did not address the question of the implications of waste management considerations for the choice of fuel cycles.

[124] APS, op. cit., p. 58.

The principal reason for this conclusion is that reprocessing and recycling do not produce a large net improvement from a waste management point of view because: 1) the benefits are not large, and 2) reprocessing and recycling generate new waste management problems that offset some of the benefits. This can be seen by considering some of the complications introduced by the two separate steps of reprocessing and recycling.

Reprocessing Operations and Costs

Reprocessing involves dissolving the spent fuel in acid and separating the fission products and unusable TRU elements from the reusable material (uranium and plutonium). Dissolving the spent fuel has several waste management benefits even if the uranium and plutonium are not removed for recycling. First, it allows the radionuclides to be separated into several streams for different types of treatment and disposal. For example, the short-lived, hot fission products (in particular, strontium-90 and cesium-137) could be segregated for separate disposal so that the long-lived fission products and transuranics could be disposed of without the complications caused by high heat output. Second, the dissolved material can then be resolidified into a low-solubility waste form, which can reduce the rate at which the waste could escape from a repository if it comes into contact with ground water.

A recent National Research Council study of geologic disposal shows that it is these effects, rather than the removal of plutonium, which give high-level waste from reprocessing an advantage compared to spent fuel. This can be seen by comparing figures 3-3 and 3-4, which show the study's best estimates of the expected doses from a basalt repository containing high-level waste and spent fuel, respectively. These figures show that, for the ground-water travel times greater than the 1,000 years required by NRC regulations, the major difference between the doses from spent fuel and high-level waste is caused by carbon-14 (C^{14}) and iodine-129 (I^{129}).[125] These two nuclides are released as gases when the spent fuel is dissolved, and can then be concentrated in a relatively few packages in a chemical form that can limit the rate at which they dissolve into ground water to a level far below the rate that is expected if they are distributed uniformly throughout a large number of spent fuel packages.[126]

The other advantage that results from dissolving the spent fuel is that it is possible to resolidify the material in a waste form that is much less soluble than the original spent fuel pellets. As noted earlier, several studies have indicated that this could be one of the most effective ways to improve repository performance significantly. As will be discussed in chapter 6, additional work on insoluble waste forms could be useful. Recent analysis suggests that both spent fuel and borosilicate glass may be unable to meet the current NRC release rate requirement for some radionuclides,[127] although NRC can modify the requirements for some radionuclides on a case-by-case basis. In any case, use of a less soluble waste form for spent fuel would not require removal of the plutonium and uranium, and dissolution and resolidification has been considered by DOE as one method for treating spent fuel for direct disposal in a once-through fuel cycle.[128]

Dissolving spent fuel, packaging the C^{14} and I^{129} separately, and resolidifying the rest of the material in an insoluble form could thus improve expected repository performance. However, the important question from a waste management perspective is whether the improvements are sufficient to warrant undertaking those relatively complex steps, if reprocessing is not otherwise being done anyway to recover the plutonium and uranium. There are several considerations that underlie the judgment cited above that the advantages are not sufficient:

1. *Reprocessing involves increased near-term operational risks.* Reprocessing spent fuel would increase the amount of handling and processing of highly radioactive materials prior to disposal of the waste, increasing worker exposures and population exposures during normal operations and producing addi-

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[125] The doses resulting from the differences in content of plutonium or uranium, and their decay daughters, like radium-226 (Ra^{226}), are at much lower levels because they are expected to dissolve much more slowly than the the waste form that contains them, and to be retarded strongly by the material surrounding the repository so that they substantially decay before they escape to the environment.

[126] National Research Council, *Isolation System*, p. 282.

[127] Ibid., p. 239.

[128] DOE, *FEIS*, p. 4.20.

tional possibilities for accidents that could release radioactive material. For example, DOE analysis shows that normal waste management operations for a 250-gigawatts-electrical (GW_e) once-through cycle could be expected to cause from none to 2 health effects worldwide, while a comparable reprocessing cycle could cause from 6 to 750 health effects worldwide, with about 95 percent of those resulting from predisposal waste treatment operations.[129] [130] This relatively certain increase in near-term operational risks would have to be weighed against the more uncertain reduction in long-term risks that could result from reprocessing.

This same consideration also applies to any of the more sophisticated waste-management techniques that reprocessing would allow, such as use of a highly insoluble waste form, to the extent that they also involve more complex handling and processing operations. In this regard, a National Research Council panel recently concluded that the choice of solid waste forms for high-level waste from reprocessing should take into account the release of radioactivity into the environment from all stages of waste management, including waste form manufacture, rather than just the differences in expected releases after the waste is placed into a repository.[131] Similarly, as noted, analysis of the possible benefits of separating out the long-lived, toxic TRU elements and recycling them along with uranium and plutonium so that they can be destroyed by fission in reactors has concluded that the increase in operational risks and complexity involved would offset the limited advantages.

2. *Reprocessing, or even simply dissolving spent fuel and resolidifying it in another form, produces other waste forms—principally, large volumes of TRU waste—that must also be managed and ultimately disposed of.*[132] If reprocessing were initiated before a disposal facility were available, it would change the nature of the waste—from spent fuel to high-level waste from reprocessing, TRU, low-level waste, and, perhaps, unrecycled plutonium—but would not eliminate the need for waste storage. DOE estimates that the capital cost of storage facilities at a reprocessing plant could amount to around $350 million for 5 years' output of waste and at least $280 million for storage of separated plutonium, which would have to be provided unless the plutonium were recycled without delay.[133] In addition, these large quantities of additional waste forms could significantly increase the costs and risks of waste transportation.[134] Finally, TRU wastes will require the same sort of long-term isolation as the high-level waste and thus may be disposed of in the same facility. Depending on resolution of regulatory issues, such reprocessing wastes might require more repository space than spent fuel for a given amount of electricity generation.[135]
3. *Reprocessing could increase the costs of waste management if undertaken for that purpose.* It is not at all clear that there would ever be a demand for all of the plutonium that could be obtained by reprocessing all of the spent fuel from LWR's, even if a system of breeder reactors were operated.[136] In addition, there may be a financial incentive to discard some plutonium after three or more recycles, in any case, because of the buildup of undesirable radionuclides.[137] If reprocessing were required as a waste management step, then the costs

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[129] Ibid., pp. 7.39-7.40.

[130] The recent German fuel cycle study has also concluded that a reprocessing fuel cycle would increase worker and population exposures compared to direct disposal of spent fuel. Closs and Geipel, op. cit.

[131] National Research Council, *Isolation System*, p. 14.

[132] See DOE, *FEIS*, sec. 4.3.1 for TRU wastes produced by spent fuel processing options and sec. 4.3.3 for TRU wastes produced by reprocessing.

[133] DOE, *FEIS*, vol. 2, app. A, table A.8.8, p. A.102. APS, op. cit., p. 62, notes that the cost of storing separated plutonium for 10 years is much greater than the cost of storing spent fuel for the same period.

[134] Wilmot et al., *A Preliminary Analysis*, op. cit. See also T. I. McSweeney, R. W. Peterson, and R. Gupta, "The Costs and Impacts of Transporting Nuclear Waste to Candidate Repository Sites in *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting* (Washington, D.C.: U.S. Department of Energy, February 1984), pp. 351-361.

[135] DOE, *FEIS*, p. 7.29, table 7.3.10. This analysis takes into account the effects of plutonium recycle on the heat output of, and thus the repository space required for, high-level waste.

[136] The MITRE Corp., *Analysis of Nuclear Waste Disposal and Strategies for Facility Deployment* (McLean, Va.: April 1980), a report prepared for the Office of Technology Assessment; and Brian G. Chow and Gregory S. Jones, "Nonproliferation and Spent Fuel Disposal Policy," a report prepared for the Council on Environmental Quality (Marina Del Ray, Calif.: Pan Heuristics, October 1980).

[137] DOE, *FEIS*, p. 7.30.

of reprocessing that were not offset by sale of recovered plutonium and uranium would have to be added to the waste management costs.

Comparisons of the costs of disposing of spent fuel and high-level waste show relatively little difference between the two approaches, with some studies showing an advantage for high-level waste and others an advantage for spent fuel.[138] For example, current DOE estimates show that the cost of disposal of spent fuel would be about $122 to $125/kilogram (kg), while the cost of disposing of the reprocessing waste equivalent would be $115 to $119/kg; if the $8/kg cost of solidification of the high-level waste is included, total waste management costs for high-level waste would slightly exceed the costs for direct disposal of spent fuel.[139] In comparison, the costs of reprocessing could be several times as high. For example, DOE currently uses $390/kg as a reference cost for reprocessing LWR fuel, with a possible range of from $200 to $600/kg.[140] Since the range of uncertainty in the cost of reprocessing is greater than the total estimated cost of waste disposal, it is highly unlikely that the very small difference in disposal cost between spent fuel and high-level waste would play a significant role in a decision about whether to undertake reprocessing.

Even if high-level waste could be disposed of for free, the cost advantage would not by itself offset the cost of reprocessing. Thus, a waste policy requirement for reprocessing spent fuel that would otherwise not be reprocessed for economic reasons could substantially increase the costs of waste management. (This would be the case even if the only processing involved were dissolution of spent fuel and resolidification in borosilicate glass, without separating the plutonium and uranium—a step which DOE estimates would increase the cost of waste management in a once-through cycle by about 60 percent.[141])

Since neither EPA nor NRC have concluded that unprocessed spent fuel would not be an acceptable waste form, there may be little incentive for incurring the additional costs and operational risks of reprocessing (or other processing) simply to improve repository performance beyond a level that is already judged to be satisfactory. Similar considerations also would apply to any more complex and expensive waste processing steps allowed by reprocessing that promise to reduce long-term risks below the level presented by direct disposal of spent fuel. Reprocessing could allow use of more complex disposal system technologies than those possible with direct disposal of spent fuel. For example, it could allow separation and separate disposal of the heat-producing, but relatively short-lived, fission products from the cool, but very long-lived, transuranics, or the use of disposal systems such as space disposal, which are not practical with spent fuel. Similarly, it could allow use of very insoluble waste forms and/or waste forms that are tailored to the characteristics of the repository host rock.

However, unless these alternative disposal options prove less expensive than simpler systems or are required by law or by regulation for safety reasons, they may not be used—even if reprocessing were undertaken for resource recovery reasons. For example, as mentioned earlier, recent analysis has shown that increased waste management costs, as well as increased operational risks, would probably preclude partition and transmutation of long-lived radionuclides in reactors, even if spent fuel were already being reprocessed routinely.[142] Similarly, if a very low-solubility waste form proved to be significantly more expensive than a more soluble but still acceptable one (which borosilicate glass may prove to be), it is not clear that the additional expenditures would be made unless there were a regulatory requirement for the more expensive waste form. The same reasoning, of course, would apply to the choice between spent fuel and reprocessed waste as a waste form.

Effects of Plutonium Recycle on Waste Management

So far, we have considered only the waste management benefits and costs associated with chemical processing of spent fuel per se. Some of the potential waste management advantages of high-level waste compared to spent fuel result from removing the plutonium and recycling it so that it is destroyed by fission in nuclear reactors rather than being disposed of. However, like the initial step of reprocessing, which is required for separating the plutonium in the first place, the additional step of plutonium recycle generates waste management problems that offset the advantages to some extent.

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[138] Ibid., p. 7.50 shows slightly higher costs for reprocessing waste; INFCE, *Summary Volume*, p. 232, shows about a 10-percent advantage for reprocessing waste.

[139] DOE, *Report on Financing the Disposal*, op. cit., p. 2.

[140] U.S. Department of Energy, *Nuclear Energy Cost Data Base*, DOE/NE-0044/2 (Washington, D.C.: March 1984), table 2.12, p. 24.

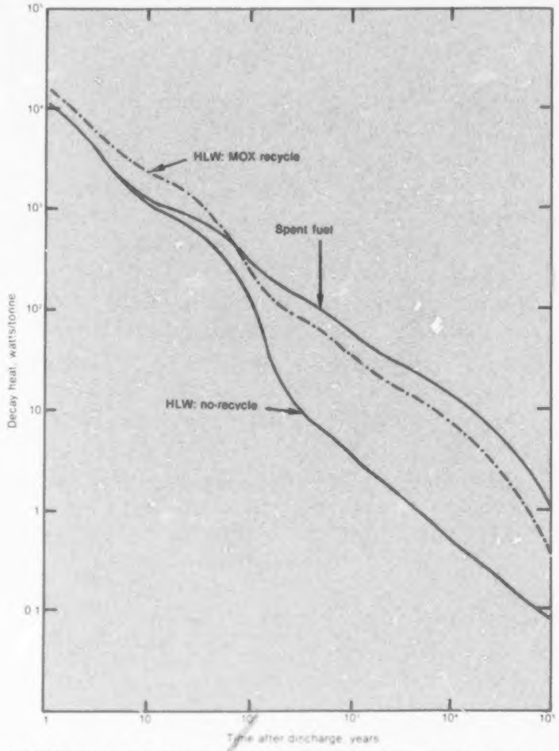
[141] Derived from *FEIS*, table 4.9.7, p. 4.110.

[142] Croff et al., op. cit.

First, recycle of plutonium reduces the difference between once-through spent fuel and high-level waste. As noted in chapter 2, plutonium recycle increases the toxicity and heat output of the resulting high-level waste. Thus, as recycle continues, the resulting high-level waste from reprocessing spent mixed-oxide (MOX) fuel containing recycled plutonium becomes more and more similar, in toxicity and heat output, to once-through spent fuel containing no recycled plutonium.[143] This effect is increased by the delay in reprocessing, which, as discussed in chapter 2, will also increase the toxicity and heat output of the resulting high-level waste.

The effect of plutonium recycle on the heat output of high-level waste can be seen in figure 3-7, which shows the heat output of once-through spent fuel (SF UO_2), high-level waste with no plutonium recycle (HLW UO_2), and high-level waste with plutonium recycle (HLW MOX). The heat output of HLW MOX is actually higher than once-through spent fuel for the first 100 years, the period during which the maximum temperature increases in a repository are expected.[144] This could reduce one of the advantages sometimes cited for reprocessing—i.e., its ability to reduce the volume of waste, since the unused uranium and plutonium (representing about 95 percent of the volume of the spent fuel) would be separated for reuse. The actual reduction that could be achieved will depend on the amount of heat-producing, high-level waste that can be placed in each canister, which in turn will depend on the temperature limits established for the waste package and the repository and on the heat output of the waste. The nearer the heat output of high-level waste to that of once-through spent fuel, the less the advantage of high-level waste in terms of volume and number of waste canisters. Furthermore, any volume reduction that results from reprocessing and recycle may not reduce proportionately the total amount of repository space needed to dispose of the waste from the generation of a given amount of nuclear electricity, since it is the total amount of heat-producing isotopes in the waste, rather than the waste's physical volume, that is the principal determinant of the total repository area required.

Figure 3-7.—Decay Heat Power for Different Nuclear Fuel Cycles for a Pressurized Water Reactor



SOURCE: Wang, et al., *Thermal Impact of Waste Emplacement and Surface Cooling Associated With Geologic Disposal of Nuclear Waste*, NUREG/CR-2910 (Washington, DC: U.S. Nuclear Regulatory Commission, 1983).

Secondly, considerable centralized control of the nuclear power system may be needed to eliminate all of the plutonium recovered by reprocessing. While recycle destroys plutonium by fission in reactors, it also produces plutonium from U^{238}, so that the total amount of plutonium present in a reprocessing cycle is greater than that in the once-through cycle.[145] Thus, if reprocessing and recycle were undertaken to reduce the amount of plutonium that must be disposed of compared to a once-through cycle, careful planning and management would be needed to minimize the amount of plutonium left when the nuclear power system is eventually phased out.

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[143] DOE, *FEIS*, p. 7.53.

[144] Ibid., app. K.

[145] Ibid., p. 7.30.

In addition, recycle may have to be continued for an extended period to obtain major reductions of plutonium compared to those from a once-through cycle. For example, DOE calculates that a once-through nuclear power system that reaches 250 GW_e in the year 2000 and phases out by 2040 would produce about 1,900 tonnes of plutonium to be disposed of in spent fuel. In comparison, a reprocessing cycle for the same generating scenario would produce about 3,400 tonnes of plutonium, about 1,100 tonnes of which would still be unrecycled in 2040 even if reprocessing and recycle began as early as 1990.[146] Clearly, nuclear power generation and recycle would have to be continued considerably beyond 2040 to reduce the amount of unrecycled plutonium to a small fraction of the plutonium discarded in the once-through cycle. Since it is not clear that economic factors would lead utilities to manage their systems so as to reprocess all spent fuel and to recycle all of the recovered plutonium, some form of Federal intervention (e.g., a regulation requiring that utilities deliver solidified high-level waste for disposal, or Federal operation of reprocessing facilities and of reactors for using the plutonium), might be needed to minimize the amount of unrecycled plutonium.

Conclusion

Available analysis strongly supports the conclusion that reprocessing is best viewed as a possible measure for extending energy resources rather than as a waste management step. Analysis of the merits of reprocessing and recycle from the perspective of energy needs is beyond the scope of this study. However, it is not necessary at this time to decide when and how much spent fuel will be disposed of or reprocessed, since that decision will not be faced until a disposal capability is available. At that time, if commercial reprocessing has not commenced, a decision will have to be made either to maintain the spent fuel in surface (or near-surface) storage facilities at reactor sites, repository sites, or other independent sites; to store the spent fuel in a geologic repository that could be backfilled at a later date; or to dispose of the spent fuel in mined repositories. If that decision is to be based primarily on the resource value of the spent fuel rather than on the capability to dispose of spent fuel or high-level waste from reprocessing, the capability to dispose of both spent fuel and high-level reprocessing waste will have to be developed. (For further discussion of this point, see issue 3 in app. B.)

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[146] Ibid., table 7.3.12, p. 7.31.

INTEGRATED WASTE MANAGEMENT SYSTEM

To manage the annual flow of spent fuel generated by operating nuclear reactors, waste management will entail the construction and operation over a long period of time of some combination of the technologies described above. Most analyses of radioactive waste management to date have concentrated on individual components—spent fuel storage, transportation, or disposal—rather than on their integrated operation in a full-scale system.[147] Only in the last several years have the analytical tools been developed that (if properly combined) would allow a systematic comparative analysis of different waste management system designs and optimization of the entire system.[148] As a result, there are a number of important questions of system design for which relatively little systematic analysis exists. For this reason, OTA's analysis of these questions has been based on inference from a number of partial analyses, some performed specifically for this assessment.

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[147] The DOE *FEIS* did use a systems model to analyze the impacts of operation of the total waste management system.

[148] Recent analysis of waste transportation system issues concludes that greater interaction is needed among persons involved in repository design, transportation system development, and waste generation. Comments of NWTS Transportation Interface Technology Peer Review Panel, in Clinton G. Shirley, *NWTS Transportation Interface Technology Development Priority Report*, SAND82-1804 (Albuquerque, N. Mex.: Sandia National Laboratories, July 1983), p. 9-14.

A more comprehensive analysis of system design must await development and use of an integrated system model that combines the partial models that have been developed by DOE. In particular, we note that integration of the capabilities of the existing Integrated Data Base[149] (projections, source-terms, and process tradeoff analyses), transportation systems analysis capabilities[150] (routing and logistics), repository systems analysis capabilities[151] (design/cost tradeoffs), repository risk analysis[152] (radiological impact of repository), and any one of numerous health impact models[153] would result in a system model capable of performing a variety of cost/risk/benefit/scheduling studies necessary for efficient planning and operation of the waste management system. The complexity of these models and the specialized expertise necessary to implement them will likely require implementation of the integrated model in pieces at various sites, with results being communicated using computer-compatible methods (magnetic tapes). The importance of developing an integrated system model is discussed further in chapter 6.

System Impacts

Health Effects

Waste management may result in small, localized releases from accidents during waste handling, transportation, and storage activities prior to disposal. However, there appears to be little, if any, chance of massive, uncontrolled releases of radioactivity into the environment in a short period of time that would cause a large number of health effects (in contrast to the possibility, however remote, of a meltdown in a reactor). Instead, the principal radiological effects during waste management prior to disposal would result from radiation doses to workers and the public during routine operations.[154]

Analyses indicate that after disposal in a geologic repository, the two principal modes of release would be: 1) small, concentrated releases produced by human intrusion (from digging a well either near or into a repository) that could result in large doses of radiation to a few individuals; or 2) the gradual release of radioactivity from the repository into ground water (and ultimately into drinking water or food supplies), leading to very small doses (compared to background radiation) to a large portion of the population. DOE analysis calculates that normal operation of a waste management system without reprocessing could be expected to produce, at most, two health effects (genetic disorders or fatal cancers) over a 70-year period, even if the level of nuclear power generation increased to 500 GW_e by 2040.[155] The addition of reprocessing increases the maximum expected health effects to 37 on a regional basis and 1,100 worldwide for the same level of generation.[156] While this is a large number in absolute terms, it nonetheless represents only a small fraction (0.003 percent) of the health effects to the world population expected to result from natural sources of radioactivity over the same period.[157] A review of the risks associated with nuclear power, conducted by the National Academy of Sciences, concludes that the total exposure to future generations from wastes released from a repository should not exceed the doses to the present generation from normal operation of the nuclear fuel cycle.[158]

Nonradiological Impacts

Even if there are no significant direct health effects from radioactive releases, management of high-level radioactive wastes will have ecological, land-use, manpower, and community adjustment impacts. In general, the nonradiological health and environmental effects from constructing and operating a geologic repository should be no more severe than those associated with other large construction projects.[159] In particular, the anticipated nonradiological impacts arising from the resource and economic requirements of nuclear waste management occur in similar and ongoing activities associated with preparation of fresh nuclear fuel and coal mining. For example, the largest coal mines dwarf mined geologic repositories as geographically concentrated sources of nonradiological, ecological, and community impacts.[160] The waste storage and disposal system should add, at most, about 20 percent of the land area to the land area required for the mills and reactors they serve. When all of the other facilities such as uranium mines and enrichment plants are taken into account, it appears unlikely that high-level radioactive waste management would ever require an appreciable fraction of the total land area serving the nuclear fuel cycle.[161]

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[149] K. J. Notz, "Radwaste Inventories and Projections: An Overview," USDOE Report ORNL/TM-8322, July 1982.

[150] D. S. Joy, B. J. Hudson, and M. W. Anthony, "Logistics Characterization for Regional Spent Fuel Repositories Concept," USDOE Report ONWI-124, August 1980.

[151] L. L. Clark and B. M. Cole, "An Analysis of the Cost of Mined Geologic Repositories in Alternative Media," USDOE Report PNL-3949, February 1982.

[152] D. J. Silviere et al., "A Short Description of the AEGIS Approach," USDOE Report PNL-398, September 1980.

[153] M. Mills and D. Vogt, "A Summary of Computer Codes for Radiological Assessment," USNRC Report NUREG/CR-3209, March 1983.

[154] Closs and Geipel, op. cit.

[155] DOE, *FEIS*, table 7.4.3, p. 7.40.

[156] Ibid., table 7.4.4, p. 7.40.

[157] Ibid., p. 7.39

[158] National Academy of Sciences, *Risks Associated with Nuclear Power: A Critical Review of the Literature*, Summary and Synthesis Chapter (Washington, D.C.: 1979), p. xi.

Construction and operation of waste storage and disposal facilities are likely to have effects on nearby communities similar to those of mining or industrial warehousing. Development of a repository could create a noticeable increase in local population, particularly during the construction phase, that could require careful planning for expanded public services and housing. Such "conventional" impacts have been experienced and dealt with during industrial developments of many kinds; they are not unique to radioactive waste management.[162] (See table 3-5.) However, the socioeconomic impacts of a repository are likely to be very site-specific and difficult to predict on the basis of experience with other types of facilities at other sites.[163]

A less tangible and familiar community impact of waste management and disposal would be the effect of public concerns about the radiological health and safety risks of waste management operations—concerns that would not exist to such a degree about more familiar industrial activities.[164]

Table 3-5.—Conventional Site Effects of a Large Industrial Facility

1.0 Economic Effects
1.1 Change in property value
1.2 Change in rental costs
1.3 Change in cost of goods and services
1.4 Higher property taxes
1.5 Change in employment
1.6 Change in provision of jobs
1.7 Change in travel costs
1.8 Change in market areas and competitive position of economic activities

2.0 Environmental and Health Effects
2.1 Noise
2.2 Air pollution
2.3 Damage to soil quality
2.4 Water drainage damage
2.5 Vibration
2.6 Congestion and access
2.7 Accidents
2.8 Aesthetic changes

3.0 Social Change Effects
3.1 Social pathologies (alcoholism, drug abuse, mental illness, divorce, juvenile delinquency)
3.2 Crime
3.3 Personality adjustment
3.4 Affectual relations
3.5 Use of community facilities
3.6 Intergroup conflict
3.7 Quality of public services
3.8 Sense of community (includes sense of attachment, support networks)

4.0 Location Transfer Costs and New Location Effects
4.1 Searching
4.2 Moving
4.3 Capital financing costs
4.4 Start-up and operating costs (businesses)
4.5 Personality adjustment

5.0 Institutional Adaptations
5.1 Land-use functions
5.2 Development planning
5.3 Negotiations with contractors, government agencies
5.4 Conflict resolution
5.5 Jurisdictional issues
5.6 Public service bureaucracies; direct-service agencies
5.7 Division of responsibilities

SOURCE: National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal (Washington, DC: National Academy Press, 1984)*.

There might also be important community impacts resulting from the controversy that could surround the siting of waste facilities.[165] In any case, evidence suggests that the public perceives radioactive waste management to be qualitatively different from other superficially similar operations and industries.[166] This has led some analysts to conclude that a systematic effort to identify and understand those impacts that cause the greatest public concern might be needed to avoid repetition of past conflicts in the implementation of the Federal waste management program.[167] A National Research Council panel recently concluded that the "special" effects associated with the radiological aspects of radioactive waste management might be particularly difficult to assess, but could exceed the conventional effects of a repository and prove difficult to mitigate or eliminate.[168]

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[159] National Research Council, *Social and Economic Aspects*, p. 93.

[160] The MITRE Corp., *Assessment of the Non-Radiological Impacts of Managing Commercially Generated Spent Fuel*, April 1981, a report prepared for the Office of Technology Assessment, pp. 2-22, 2-23.

[161] Ibid., p. 2-8.

[162] Ibid., p. 2-13. See also Roger Kasperson, *Anticipating the Socioeconomic Impacts of Nuclear Waste Facilities on Rural Communities*, Center for Technology, Environment, and Development, Worcester, Mass., Testimony prepared for the Rural Development Subcommittee of the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, Aug. 26, 1980, p. 6.

[163] National Research Council, *Social and Economic Aspects*, p. 12.

[164] Steve H. Murdock, F. Larry Leistritz and Rita R. Hamm, *Nuclear Waste: Socioeconomic Dimensions of Long-Term Storage* (Boulder, Colo.: Westview Press, 1983), p. 112.

[165] Kasperson, *Anticipating the Socioeconomic Impacts*.

The acceptability of waste management activities to a community may depend not only on their actual or perceived impacts but also on the benefits the community expects to receive from the activities. While studies of the socioeconomic effects of radioactive waste management facilities have generally focused on the negative impacts, operation of a geologic repository will have some positive impacts as well. As with any industrial facility, the repository will bring some jobs to the community. In addition, the first repository—which is likely to be the first such facility in the world—may well become an international research center on radioactive waste disposal for a period extending well beyond the time when the repository ceases active operation. This could lead to long-term community benefits that might to some extent offset the more immediate but short-term impacts of repository construction. In fact, some communities that are already familiar with nuclear activities and are interested in the financial benefits of waste management have indicated willingness to host waste facilities.[169]

Generally, Federal activities are less attractive financially to local communities than those of commercial industry because the Federal Government does not pay local taxes. Because the adverse impacts of repository development and operation have the potential for substantial harm to the host community, provision of resources to reduce, mitigate, and compensate for such impacts may be required.[170] Authority for this response was included in the NWPA (see chs. 5 and 8).

Transportation

The transportation of high-level radioactive waste will be the aspect of waste management that affects the largest number of States and communities. The actual risks posed by transportation appear to be low, although transportation is the predisposal waste management step with the potential for the most serious accidental release of radioactive material.[171] The transportation of high-level radioactive waste through a community will place some demands on State and local governments to maintain some emergency response capability for shipping accidents, whether or not any release of radioactive material occurs. The actual number of communities affected in this way will be highly dependent on the nature of the waste management system that is developed—whether it is highly centralized, with one large repository or interim storage facility operating at any one time, or decentralized, with several operating facilities distributed around the country. The more centralized the system, the greater the number of communities affected by transportation of spent fuel from reactors to storage or disposal.

A qualitative idea of the different transportation implications of centralized and decentralized waste management systems can be obtained by comparing figures 3-8 and 3-9. These figures show the projected annual shipments to a single western storage site and to three regional storage sites in the year 2004, assuming that 113 reactors are in oper-

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[166] Roger E. Kasperson et al., "Public Opposition to Nuclear Energy: Retrospect and Prospect," *Science, Technology, and Human Values 31*, spring 1980, pp. 11-23; and J. A. Herbert et al., *Nontechnical Issues in Waste Management: Ethical, Insitutional, and Political Concerns* (Seattle, Wash.: Human Affairs Research Centers, Battelle Memorial Institute Pacific Northwest Division, May 1978).

[167] Gene I. Rochlin, "The Role of Participatory Impact Assessment in Radioactive Waste Management Program Activities," Institute of Governmental Studies (Berkeley, Calif.: 1981), pp. 43-44.

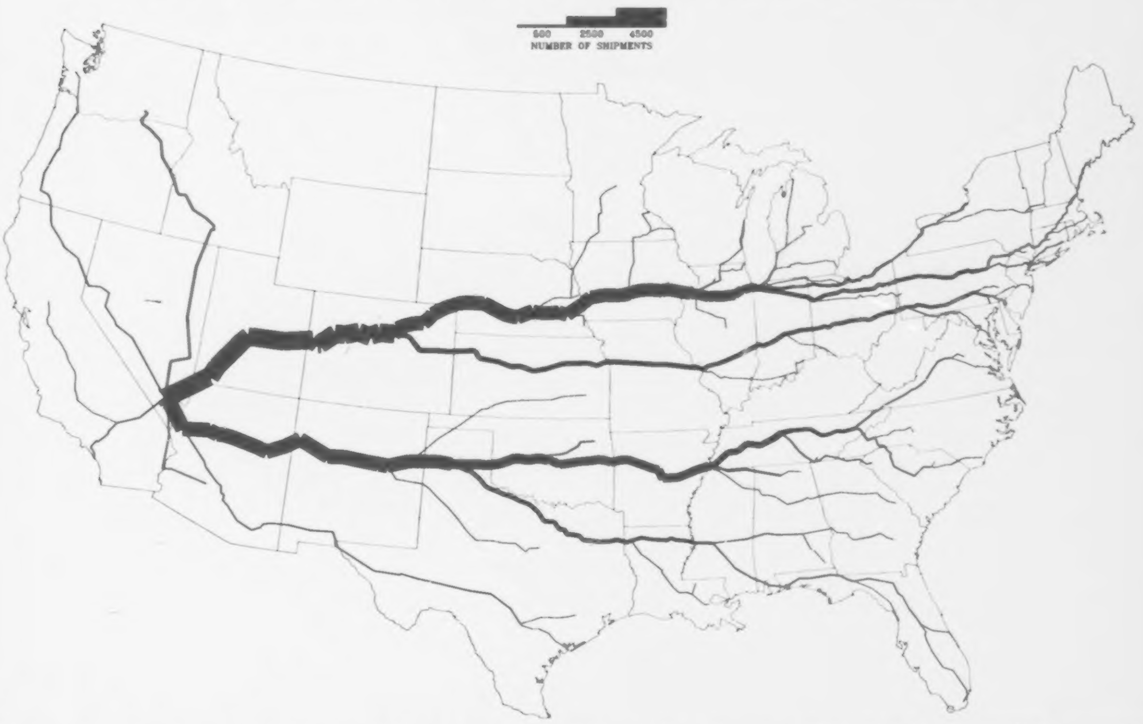
[168] National Research Council, *Social and Economic Aspects*, p. 101.

[169] "Nuclear Waste War Cry: 'Not Here, You Don't!'," *U.S. News & World Report*, Aug. 15, 1983, pp. 23-24; "To Keep Their Town Alive, the Residents of Naturita, Colo. Want a Nuclear Dump," *The Wall Street Journal*, July 1, 1982, p. 1.

[170] National Research Council, *Social and Economic Aspects*, p. 12. See also S. A. Carnes et al., *Incentives and the Siting of Radioactive Waste Facilities*, ORNL-5880 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, August 1982).

[171] DOE, *FEIS*, p. 4.98.

Figure 3-8.—Spent Fuel Shipments in a Centralized Waste Management System



Projected annual shipments to a western site in 2004, assuming truck shipments from all reactors. (Site selected for demonstration purposes only. The site shown is only one of several western sites now under consideration for a repository, and is used as a convenient hypothetical example only.) The actual number of annual shipments is likely to be lower because of use of new casks designed for older spent fuel, which will carry more per shipment, and shipment of some fuel using much larger rail casks.

SOURCE: National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal* (Washington, DC: National Academy Press, 1984).

ation at that time and that all shipments are made by truck.[172] The shipments represent about 13,000 spent fuel assemblies containing about 3,700 tonnes of fuel.[173] One rough indicator of the difference between the centralized and decentralized systems is the total shipping distance involved. Assuming for simplicity that all shipments were made by truck, the shipping distance in 2004 would be about 9 million miles for the regional system, compared to about 33 million miles for the single western site.[174] Both the costs and risks of transportation will increase with the total transportation distance. For example, a recent analysis showed that the costs and risks (from radiation exposure and nonradiological accidents) would be about two to three times greater for a repository in the westernmost area now under consideration, Hanford, than for a repository in the easternmost area under consideration, the Gulf Interior region.[175] Other analysis has con-

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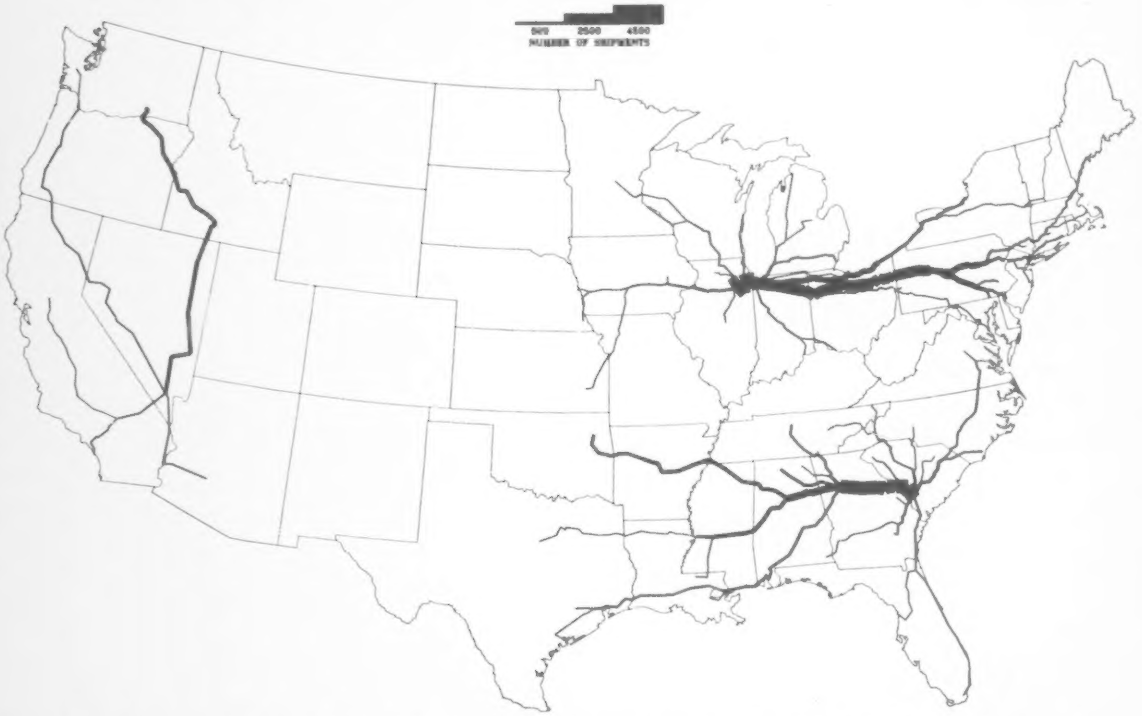
[172] These examples are drawn from a more extensive analysis of the effects of centralized and decentralized systems on transportation in National Research Council, *Social and Economic Aspects*, ch. 3. The sites shown were selected for demonstration purposes only, to show the effects of regional v. centralized storage or disposal. Only one of the sites, in southern Nevada, is now under consideration for a geologic repository. The two eastern sites are the inoperative reprocessing facilities at Morris, Ill., and Barnwell, S.C., which were considered by the Carter administration as possible sites for Federal away-from-reactor storage facilities, and which were sometimes used as hypothetical storage sites for analytical purposes. The Nuclear Waste Policy Act of 1982 forbids the acquisition of these facilities for Federal interim storage, and the sites have not been, and are not now, under consideration for geologic repositories.

[173] Ibid., app. A, p. 151.

[174] Ibid., table A.18, p. 166, and table A.14, p. 162.

[175] T. I. McSweeney et al., "The Costs and Impacts of Transporting Nuclear Waste to Candidate Repository Sites," *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting* (Washington, D.C.: U.S. Department of Energy, 1984), pp. 357-359.

Figure 3-9.—Spent Fuel Shipments in a Decentralized Waste Management System



Projected annual shipments to regional sites in 2004, assuming truck shipments from all reactors. (Sites selected for demonstration purposes only. The eastern sites are *not* under consideration for repositories and are used as convenient hypothetical examples only.) The actual number of annual shipments is likely to be lower because of use of new casks designed for older spent fuel, which will carry more per shipment, and shipment of some fuel using much larger rail casks.

SOURCE: National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal* (Washington, DC: National Academy Press, 1984.)

cluded that the costs and risks of waste transportation could be reduced by as much as a factor of 2 with an optimally sited system using two or three repositories compared to a single repository.[176]

Cost

The aggregate costs of high-level radioactive waste management will be in the tens of billions of dollars, the actual amount depending on the scale of nuclear power generation, the time that disposal occurs, and the geologic medium used for the repository. DOE has estimated that if disposal began in 2010, the cost of waste management would be up to $18 billion for the currently operating reactors and up to $68 billion for a 250-$GW_e$ system.[177] These very large absolute figures are relatively small, however, compared to the total capital cost of the nuclear power system that would be served.

Since the expenditures for waste management occur substantially later than do the initial capital expenditures for the reactor system, discounting to take into account the time value of money reduces the relative effect of waste management on the overall cost of generating nuclear electricity. As a result, it appears unlikely that the costs of waste management could ever represent more than a relatively small fraction of the total cost of nuclear power generation. DOE, in its analysis of waste management alternatives for a range of nuclear power futures, concludes that the costs of waste management would add not more than 2 to 10 percent, and most likely not more than 3 percent, to the cost of nuclear electricity.[178] For this reason the fees for radioactive waste disposal are likely to be small in comparison to the effects on the costs of coal-generated electricity resulting from clean air regulations.[179]

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[176] K. D. Kirby et al., op. cit.

[177] DOE, *FEIS*, table 7.62, p. 7.47. Also, the most recent DOE analysis concludes that the cost of disposing of 144,000 tonnes of spent fuel or equivalent high-level waste—about the amount expected to be generated by the reactors now in operation or under construction—is between $18 billion and $20 billion in constant 1982 dollars. U.S. Department of Energy, *Report on Financing the Disposal*, op. cit., p. 2.

Since these fees would be seen by the utility as an annual cost, instead of an increase in the capital cost of building a nuclear powerplant, it appears unlikely that waste management costs could significantly affect a utility's decisions about whether to construct a new nuclear reactor. This conclusion is strengthened by the fact that the estimated cost of waste disposal is small compared to the total cost of fresh fuel,[180] and in fact, may be no greater than the range of uncertainty in the estimates of the cost of fresh fuel.[181]

The greatest potential cost impact of nuclear waste management policy may not be the direct costs of the management system, but the indirect costs that would result if problems in development or operation of such a system led to shutting down reactors or to a moratorium on operation of new ones. For example, the cost of replacement power for a 1-GW_e reactor for 1 year could exceed the estimated cost of storing and disposing of the total amount of high-level radioactive waste generated from the operation of that reactor during its lifetime.[182]

Distribution of Impacts

Since waste management is apt to represent only a small part of the total costs, logistics, and social impacts of the entire nuclear fuel cycle,[183] the choice among management systems will have little incremental effect on the overall impacts of nuclear power generation. However, available studies have considered only the aggregate impacts of alternative systems. The distribution of those impacts among the private sector, the Federal Government, and regions of the country has not been analyzed rigorously, even though it underlies the equity judgments that are at the heart of the political decisionmaking process.[184] Usually, the Federal Environmental Impact Statement, the primary tool for identifying impacts, focuses almost entirely on aggregate impacts and not at all on their distribution. While alternative waste management systems may be little different in their aggregate impacts, they may differ significantly in their equity implications.[185] For example, a highly centralized system with only one repository operating at a time could substantially increase the number of communities affected by waste transportation. Thus, concerns about equity issues—in particular, the regional distribution of the costs and benefits of waste management—may play a major role in decisions about both spent fuel management and waste disposal policies.

Rigorous analysis of the regional impacts of waste management would require development of an integrated waste system model capable of dealing with specific sites and transportation routes. As noted earlier, although important components that could be used in such a model have been developed, they have yet to be combined.[186]

System Interrelationships

High-level radioactive waste management at operational scale will involve handling highly radioactive materials in quantities and at annual rates that are unprecedented. For example, from the beginning of the use of nuclear power to the end of 1980, a total of about 5,000 spent fuel assemblies were transported from reactor sites.[187] About 10,000 assemblies would have to be transported each year to feed a 3,000-tonne/yr repository.[188] Nonetheless, available analyses indicate that the flows of radioactive waste produced by existing and projected levels of nuclear power generation should be manageable, provided that careful planning is done to avoid bottlenecks and minimize the strains that could result from the rapid increase in transportation and handling when a repository or reprocessing plant begins operation.[189]

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[178] Ibid., pp. 7.50-7.51. Analysis by the Congressional Budget Office supports this conclusion. CBO, *Financing Radioactive Waste Disposal*, September 1982, p. 27.

[179] Ibid., p. xvii.

[180] A recent DOE analysis shows an example levelized fresh fuel cost of 7.7 mills/kWh, compared to a waste disposal fee of 1 mill/kWh established by the Nuclear Waste Policy Act of 1982. U.S. DOE, *Nuclear Energy Cost Data Base*, table 4.2, p. 66.

[181] MITRE, *Nonradiological Impacts*, table 2-6, p. 2-20.

[182] Ibid., pp. 2-21.

[183] Ibid., ch. 2.

[184] Roger E. Kasperson, "Institutional and Social Uncertainties in the Timely Management of Radioactive Wastes," Center for Technology, Environment, and Development, Clark University, June 30, 1980. Testimony prepared for the California Energy Commission for the Nuclear Regulatory Commission Confidence Rulemaking on the Storage and Disposal of Nuclear Waste.

[185] See National Research Council, *Social and Economic Aspects*, ch. 3.

[186] Site-specific highway and rail routing models have been developed by Oak Ridge National Laboratories. See D. S. Joy et al., *HIGHWAY, A Transportation Routing Model: Program Description and User's Manual*, ORNL/TM-8419, December 1982; and D. S. Joy et al., "Predicting Transportation Routes for Radioactive Wastes," *Waste Management 1981*, vol. 1, p. 415. These are used in Edwin L. Wilmot et al., *A Preliminary Analysis*. A nonsite-specific integrated systems model was developed for use in the U.S. DOE, *FEIS*, ch. 7.

The annual handling capacity of the elements of the waste management system is as important as the total amount of the waste in determining the behavior of the system. For example, the buildup of spent fuel in storage is determined by the difference between the rate at which spent fuel is generated by reactors and the rate at which it can be reprocessed or disposed of. If the Barnwell reprocessing plant were to begin operating at its maximum capacity of 1,500 tonnes/yr in 1995, it would take 20 years to reprocess the amount of spent fuel that had gone into storage by that time.[190] It would take somewhat more than the capacity of one additional plant of the same size to handle the 2,200 tonnes of spent fuel expected to be generated each year by the reactors that will by operating in 1995.[191] Similarly, a single waste repository of the current reference loading capacity, 3,000 tonnes/yr, would be sufficient to stop the buildup of spent fuel in storage, but not to reduce the backlogs very quickly. Thus, it appears likely that up to 90 percent of the spent fuel generated in this century will still be in temporary storage facilities (most of it at the original reactor basins) at the end of the century, even if the Barnwell reprocessing plant were put into operation or a repository began direct disposal of spent fuel during the 1990's.[192]

Increasing the annual handling capacity of the waste management system is expensive. The capital cost of a 1,500-tonne/yr reprocessing plant is estimated at $2 billion, [193] and a 3,000-tonne/yr repository is estimated to be about $3 billion.[194] The initial capital cost of a centralized spent fuel dry storage facility capable of receiving about 1,500 tonnes/yr would be about $500 million, while an additional 500-tonne/year handling module at the same site would cost about $90 million.[195] Since leaving spent fuel once it has been placed in storage at the reactor is relatively inexpensive, as noted in the discussion of storage technology, the decisions about how fast and when to remove spent fuel from storage at reactor basins will have significant cost implications that must be considered in planning for the operation of a full-scale waste management system. (For further discussion, see the analysis of the Mission Plan in ch. 6.)

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[187] Edwin L. Wilmot, *Transportation Accident Scenarios*, table XXV, p. 44.

[188] Based on an average of 3.5 assemblies/tonne of spent fuel, derived from utility projections of spent fuel discharges contained in app. B of the U.S. Department of Energy, *Spent Fuel Storage Requirements*, DOE/SR-0007, March 1981.

[189] DOE, *FEIS;* MITRE, *Analysis of Nuclear Waste Disposal;* National Research Council, *Social and Economic Aspects*.

[190] DOE, *Spent Fuel and Radioactive Waste Inventories*, table 1.2, p. 30.

[191] Ibid.

[192] Ibid., fig. C.2, p. 284; fig. C.3, p. 285.

[193] DOE, *Nuclear Energy Cost Data Base*, table 2.13, p. 27 (1983 dollars).

[194] DOE, *Report on Financing the Disposal*, table 3-4, p. 13 (1982 dollars).

[195] D. E. Rasmussen, *Comparison of Cask and Drywell Storage*, op. cit., table A.27, p. A.28 (1982 dollars).

Chapter 4

History of Waste Management: Setting the Stage

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Chapter 4

History of Waste Management: Setting the Stage

When the 97th Congress convened in 1981, almost four decades into the nuclear era, about 160 U.S. commercial nuclear plants had been built or approved for construction, and approximately 6,700 metric tons (tonnes) of commercial spent nuclear fuel containing radioactive waste had already been generated. Yet the United States still had not decided how radioactive waste should be dealt with from point of generation to point of final isolation. As a result, a host of problems had arisen that both complicated the task of developing a credible and comprehensive waste management program and cast a cloud of uncertainty over the future of nuclear power in the United States.

The passage of the Nuclear Waste Policy Act of 1982 (NWPA) in the final hours of the 97th Congress represented a major watershed in the evolution of radioactive waste management policy in the United States. The decisions made in NWPA about how radioactive waste should be managed were influenced not only by technical and institutional capabilities but also by perceptions of those capabilities—perceptions formed by the historical experience of waste management. To understand how these perceptions affected the development of waste management policy and to avoid the pitfalls of the past in implementing that policy, it is necessary to examine the history and effects of past radioactive waste management policies and practices.[1] This chapter will provide that background. The provisions of NWPA will be described and analyzed in chapter 5.

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[1] This chapter draws on *Radioactive Waste Management Policy Making*, a more detailed analysis of the history of the U.S. waste management program by Daniel Metlay, included as app. A of this report. For brevity, references to that appendix are omitted (except for direct quotations), and only references to other sources are cited in this chapter.

DEVELOPMENT OF FEDERAL WASTE MANAGEMENT POLICY AND PROGRAMS

Early History (1945-75)

Sources of Radioactive Waste

High-level radioactive waste was first produced on a large scale in the wartime effort of the early 1940's to produce plutonium for atomic weapons. Spent fuel from defense reactors was routinely reprocessed to recover uranium and plutonium, and liquid high-level waste from reprocessing was stored in storage tanks at Federal facilities—first at Hanford, Wash., and later at Savannah River, S.C., and Idaho Falls, Idaho. It was assumed that disposal could take place later, possibly at these same sites.

In 1954 the Atomic Energy Act opened the nuclear power industry to private enterprise, and the first contract for a commercial reactor was issued 2 years later. Unlike defense reactors, commercial reactors were designed primarily to produce electricity. Spent fuel discharged from commercial reactors was stored in water-filled basins at reactor sites, pending development of a commercial reprocessing facility.

Climate of Policymaking

Overseeing the burgeoning commercial nuclear industry was the Atomic Energy Commission (AEC), established by the Atomic Energy Act of 1946 to promote as well as regulate the nuclear industry's defense and commercial functions. AEC's five members were appointed by the President for 5-year terms. They in turn were overseen by the congressional Joint Committee on Atomic Energy (JCAE).

During the 1950's and 1960's, waste management received relatively little attention from policymakers. Issues of waste management paled beside the exciting, pressing challenges of reactor development and research. In addition, the early regulators and developers of nuclear power viewed waste disposal primarily as a technical problem that could be solved when necessary by application of existing technology. This belief was buttressed by the 1957 report of the National Academy of Sciences (NAS), which concluded that high-level radioactive waste could be disposed of in a variety of ways and sites in the United States.[2] Testimony of Federal and civilian experts in the 1959 oversight hearings by JCAE further endorsed this view. Daniel Metlay describes the effect of such technical optimism:

> An illusion of certainty was created where, in reality, none existed. Over the years, the sense of technological optimism embedded itself in the attitudes and thoughts of important agency policymakers. It became, in a sense, an official doctrine at AEC. There is no evidence that its validity was ever seriously questioned until the mid-1970's. This optimism facilitated fragmentation by lulling policymakers; agency personnel never fully recognized that they might create in a sequential, incremental fashion an elaborate technological structure (civilian nuclear power), only to find that the last pieces could not be made to fit. The difficulties of integrating the whole were systematically underestimated.[3]

As a result of these beliefs and attitudes, commitments of budget and personnel to the management of radioactive wastes were woefully inadequate, forcing key personnel to make stopgap decisions. Moreover, key officials tended to ignore signs that a technical approach was not working and to discount the nontechnical factors that impeded progress. Later, when it became apparent that more comprehensive action was needed to isolate waste, the organizational and technical structures were not prepared to respond rapidly enough. Although some decisions made during this time later proved to be unfortunate, at the time they were made, many appeared at least reasonable and, given the constraints at work, the most appropriate possible.

Reprocessing and Storage

The country's first large-scale efforts in waste management were defense-related and involved the reprocessing of spent fuel and the storage of liquid wastes from that reprocessing in carbon steel tanks designed to last 50 to 100 years. From 1957 to 1973, however, premature corrosion of the tanks resulted in a series of well-publicized leaks at Hanford and Savannah River. An attempt at Hanford to prevent further leaks by solidifying the wastes created a solid that remains in the tanks today and may be very difficult, if not impossible, to remove for ultimate disposal.

In 1963, AEC authorized the construction of the first commercial reprocessing plant, the Nuclear Fuel Services (NFS) facility at West Valley, N.Y. During its 6 years of operation (1966-72), the NFS plant experienced several problems. For one, the lack of enough commercial spent fuel forced the facility to reprocess well below capacity, and to reprocess defense fuel that it was not designed to handle, causing damage to equipment and other technical problems. In addition, the plant received adverse publicity about its offsite leaks of radioactive waste and about radiation exposure to some of its workers.

In 1970, AEC proposed new regulations that committed the Government to develop repositories on Federal land and required that, for safety, liquid high-level waste be solidified within 5 years of its generation and transported to the repository within 5 years after solidification. Partly to meet these new regulations, the NFS plant was closed in 1971 for modifications. For financial reasons the plant never reopened, and the 612,000 gallons of liquid wastes from its reprocessing operations remain in storage tanks at the site.

A second commercial reprocessing plant, built by General Electric at Morris, Ill., never operated because of technical and design problems. A third plant, the Allied General Nuclear Services (AGNS) facility in Barnwell, S.C., was still under construction in April 1977, when commercial reprocessing was suspended indefinitely by the Carter administration. Since the operations ceased at West Valley, no reprocessing of commercial spent fuel has occurred in the United States.

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[2] National Academy of Science/National Research Council, *The Disposal of Radioactive Waste on Land*, 1957.

[3] App. A, p. 203.

Disposal

AEC first addressed the problem of waste disposal in 1955 when it asked NAS how to structure research to establish a scientific base for the waste management program. Under the assumption that the waste to be disposed of would be dissolved at relatively low concentrations in liquid, NAS stated in its 1957 report that disposal was technologically feasible and that stable salt formations appeared to be the most promising repository medium. Such formations would theoretically prevent transport of liquid and would become self-sealing in the event of a fracture. The commitment to salt became a cornerstone of waste disposal policy for the next 20 years.

In the 1960's, improved reprocessing techniques reduced the volume and increased the thermal and radiation content of reprocessed wastes. To test the effect of these new characteristics on salt, 14 spent fuel assemblies and several heaters to raise the temperature of the salt were emplaced from 1965 to 1967 in the abandoned Carey Salt Mine at Lyons, Kans. The experiment, called Project Salt Vault, was conducted in an atmosphere of goodwill among Federal, State, and local officials: State and local officials were consulted about various aspects of the experiment, public tours of the mine were given during the experiment, and the wastes were removed at the end of the experiment, as promised. The results of this experiment showed no measurable evidence of excessive chemical or structural effects on the salt, a fact which became important 2 years later when the need suddenly arose to find a disposal site quickly.

In 1969, a fire at the Federal weapons components facility in Rocky Flats, Colo., left a large volume of low-level, plutonium-contaminated transuranic waste. Following standard procedures, officials sent the wastes to the National Reactor Test Station in Idaho for storage. Concerned that their State had become a dumping ground for waste from Colorado, Idaho's political leaders appealed to AEC Chairman Glenn Seaborg, who pledged to remove the waste by 1980. That promise, as well as the commitment to disposal expressed in the AEC regulations mentioned above, spurred AEC to search for a geologic repository site. The Lyons site was selected because:

- some, albeit very little, information had been gathered about the site during Project Salt Vault;
- a favorable reception by the local citizenry seemed likely; and
- investigations needed to prove the acceptability of the other sites would have delayed repository development by 2 years.

AEC announced in 1970 that, pending confirmatory tests, the Lyons site had been selected for the first full-scale repository. Although the degree to which AEC had consulted with State and local officials before this announcement is in dispute, AEC's decision did not have full endorsement from these officials. Moreover, State and local political opposition to the Lyons site was intense, particularly when technical problems with the site became apparent. The Government abandoned plans for Lyons 2 years later because AEC was unable to convince critics that the many mining boreholes throughout the site could be plugged reliably and because no one could account for the disappearance of a large volume of water flushed into a nearby mine.

Left without a repository, AEC requested the U.S. Geological Survey (USGS) to search for additional repository sites for defense wastes. It also proposed building a series of aboveground structures, called retrievable surface storage facilities (RSSFs), to store commercial high-level wastes for a period of decades while geologic repositories were developed. The environmental impact statement issued by AEC in support of the RSSF concept drew intense criticism by the public and by the Environmental Protection Agency (EPA) because of concerns that the RSSFs would become low-budget permanent repository sites. As a result, AEC abandoned the RSSF concept in 1975.

Recent History

Climate of Policymaking

After the mid-1970's, significant changes occurred in waste management. EPA issued its first standards—those for the preparation of reactor fuel, for reactor operations, and for reprocessing of spent fuel—and announced its intention to develop standards for the disposal of nuclear waste. The Energy Reorganization Act of 1974 abolished AEC and distributed its developmental functions to the new Energy Research and Development Agency (ERDA), later changed to the Department of Energy (DOE), and its regulatory functions to the new Nuclear Regulatory Commission (NRC). JCAE was disbanded and its role assumed by a variety of congressional committees. These events marked the change to a formal process of regulating the storage and disposal of high-level wastes. Thus, ERDA (later, DOE) would select a disposal site and design a facility to meet regulations promulgated by NRC in accordance with EPA standards.

By the late 1970's, the problem of waste isolation had captured the focus of the Federal Government, which began to allocate substantial personnel and funds to its solution. Although many decisionmakers still contended that managing high-level radioactive wastes was not technically difficult, they increasingly recognized the nontechnical aspects of the problem and worked to develop a firmer technical base from which to make decisions.

Disposal

DEFENSE WASTE

The abandonment of the Lyons site left the Government without a repository for the nuclear wastes from Rocky Flats. To fill that need, ERDA officials in 1974 selected a site near Carlsbad, N. Mex., for construction of the Waste Isolation Pilot Plant (WIPP), a pilot repository for defense transuranic waste. Initially, State and local officials supported WIPP because of its potential for boosting the economy of an area hard hit by the decline in the potash industry.

Then in 1977, the Government made the first of several dramatic changes in the scope and mission of WIPP: it considered the emplacement of defense high-level waste at the facility.[4] To ensure repository safety, ERDA also promised the licensing of the repository by NRC. Angered by the changes in scope, the New Mexico House of Representatives came within three votes of passing a constitutional amendment banning disposal of out-of-State nuclear waste. Under fire, DOE promised New Mexico officials veto rights over WIPP.

Relations were further strained in February 1978 when DOE recommended the emplacement of up to 1,000 commercial spent fuel assemblies at WIPP. Local opposition arose over the increased hazards promised by the inclusion of spent fuel; over the change in nature of the repository from pilot to permanent; and over the perception that New Mexico, which had no commercial reactors, would assume a disproportionate responsibility for the Nation's commercial nuclear waste. Moreover, critics accused DOE of putting aside technical considerations to use WIPP to satisfy laws, passed by California and under consideration in other States, requiring that a demonstrated high-level waste disposal technology approved by the Federal Government must exist before additional reactors could be constructed.

During 1978 and 1979, Congress rejected the proposals for NRC licensing and State veto powers for WIPP. These actions weakened the credibility of DOE, which had promised those provisions to New Mexico. In 1980 President Carter proposed that WIPP be terminated but that the site (now called the Los Medanos site) be retained as a candidate for a future repository. Congress refused to terminate WIPP, reactivating it as an unlicensed defense facility primarily for disposal of transuranic waste from Rocky Flats and for defense high-level waste research. Site characterization activities at WIPP, including the construction of a large shaft and exploratory tunnels, are now underway.

COMMERCIAL WASTE

For disposal of commercial high-level waste, ERDA developed the National Waste Terminal Storage (NWTS) program in 1975. The program involved a multiple-site survey of underground geologic formations in 36 States and was designed to lead to the development of six pilot-scale repositories by the year 2000—the first in salt, the rest in other geologic media. This change from preoccupation with salt reflected new views about what constituted an effective repository. As formally expressed in 1978 in "Circular 779"[5] by several USGS scientists and also in a study by the American Physical Society,[6] the effectiveness, or integrity, of a repository could be considered dependent on the combination of the emplacement medium *and* its environment, rather than on the emplacement medium alone. With that view, salt, although still a strong contender, might not be the only choice for a geologic repository. Moreover, the staff of NRC contended that "it would be highly desirable to place major, if not primary, importance on the waste form itself, its packaging, and the local waste-rock interface."[7]

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[4] This discussion of the history of WIPP is drawn from Jackie L. Braitman, *Nuclear Waste Disposal: Can Government Cope?* (Santa Monica, Calif.: The Rand Corp., December 1983), pp. 116-121.

The responses of State officials to DOE's plans for the NWTS program varied. Some States excluded ERDA from even exploring potential repository locations. Others were reluctant to welcome ERDA until further studies were completed. Thus, what began as a fresh start in the area of waste management soon got mired down in the reluctance of State officials even to contemplate a facility on their soil.

Because of lower-than-requested funding and political opposition from the States, schedules slipped repeatedly as the Government was forced to cut the program drastically. By 1980, active site evaluation research was being undertaken only in Louisiana, Mississippi, Nevada, Texas, Utah, and Washington.

Recent Waste Management Policy

THE CARTER ADMINISTRATION

Partly to ease the utilities' growing burden of spent fuel storage, President Carter announced in his spent fuel policy in 1977 that title to spent fuel would be transferred to the Government and that the spent fuel would be transported at utility expense to a Government-approved away-from-reactor facility for storage until a repository became available. A one-time fee for Government storage and disposal would be charged to the utility. To limit the availability of weapons-grade material, President Carter extended the moratorium on reprocessing, set in the Ford administration in 1976, by suspending indefinitely the reprocessing of commercial spent fuel in the United States. The policy also offered to provide limited storage and disposal of foreign spent fuel, if necessary to meet nonproliferation objectives, and committed substantial resources to development of mined geologic repositories.

To help develop his administration's policy on long-term nuclear waste management, President Carter established in 1977 the Interagency Review Group (IRG), composed of representatives from 14 Government agencies. IRG submitted its report in 1979, and in 1980 President Carter ratified the unanimous conclusions of IRG, recommending:

1. proceeding with the geologic disposal program;
2. increasing State and Indian tribe involvement in repository siting;
3. preparing a detailed National Plan for Nuclear Waste Management; and
4. developing better participation programs for the general public and the technical community.

In addition, he required characterization of more sites in a variety of media prior to submission of a license request to NRC, an issue on which IRG had been unable to reach a consensus.

To formalize the relationship between DOE and the States, IRG formulated the concept of "consultation and concurrence," first proposed by the National Governors' Association. Under this concept, a State would be consulted by the Government and given the opportunity to concur with each step in developing a repository. By not concurring, a State could effectively exercise a veto. To advise the Federal Government on key radioactive waste management issues, President Carter created the State Planning Council (SPC), a 14-member council of Governors, State legislators, an Indian tribal government representative, an observer from NRC, and representatives from DOE, the Department of Transportation, and EPA. SPC recommended that a State's nonconcurrence be overridden, or preempted, by the Federal Government only through a Presidential determination backed by both Houses of Congress.

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[5] J. D. Bredehoeft, A. W. England, D. B. Stewart, N. J. Trask, and I. J. Winograd, "Geologic Disposal of High-Level Radioactive Wastes—Earth Sciences Perspectives," Geological Survey Circular #779, U.S. Geological Survey, 1978.

[6] "Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management," *Reviews of Modern Physics*, vol. 50, No. 1, pt. II, January 1978.

[7] App. A, p. 219.

96TH CONGRESS

Nearly 50 bills concerning waste management were introduced in the 96th Congress. The Senate passed a bill which emphasized development of long-term, monitored storage facilities that permitted the retrieval of the emplaced waste. The House passed a bill that focused on a timetable for development of mined repositories. However, no acceptable compromise could be reached between the two bills, largely because of disagreements about the power States should be given with respect to siting of defense waste repositories.[8] As a result, the effort to pass comprehensive high-level radioactive waste management legislation during the 96th Congress failed.

THE REAGAN ADMINISTRATION

In 1981 the Reagan administration declared its support for nuclear power and declared an "intent to demonstrate the permanent storage of high-level radioactive waste as soon as possible."[9] The administration lifted the ban on commercial reprocessing, and DOE adopted the assumption that the reference waste form for disposal would be solidified high-level waste rather than spent fuel. However, DOE efforts to encourage private investment in reprocessing have been unsuccessful The Reagan administration also withdrew the Carter administration's offer to provide Federal storage facilities for spent fuel and left utilities with the primary responsibility for storing spent fuel until reprocessing or disposal facilities are developed.

With regard to repository siting, the Reagan administration reduced to three the number of sites that were to be examined prior to selecting a first site for licensing; the Carter administration had planned to evaluate four to five sites before making the selection. The three sites were expected to be in basalt formations at Hanford, in volcanic tuff at the Nevada Test Site, and in a salt formation at a site to be determined in 1983. Construction of exploratory shafts for in situ testing was planned to begin in 1983. After completion of the shafts in 1985, one of the three sites was to be selected for the development of an unlicensed test and evaluation facility for development of waste emplacement technology. This facility was planned to be ready to accommodate up to 200 to 300 packages of solidified high-level waste by 1989.

The first license application for a full-scale facility was expected to be submitted to NRC by 1987 or 1988. Review of the license application would be conducted by NRC in parallel with further development of the unlicensed test and evaluation facility. The first repository was expected to be constructed and licensed for operation between 1998 and 2001.[10]

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[8] Both Houses agreed that the host State's objection would be sustained with regard to a repository for commercial high-level waste if either the House of Representatives or the Senate affirmatively concurred, but they were unable to agree to a procedure for dealing with a State's objection to a repository for defense high-level waste.

[9] This description of the waste management policy of the Reagan administration is drawn from the statement of Kenneth Davis, Deputy Secretary of Energy, before the Subcommittee on Energy and the Environment, Committee on Interior and Insular Affairs, U.S. House of Representatives, July 9, 1981.

[10] A similar schedule was ultimately incorporated in NWPA and is discussed at greater length in chs. 5 and 6.

PROBLEMS FOR WASTE MANAGEMENT POLICY

Key Policy Issues

Two major related waste management issues faced the 97th Congress when it began to consider radioactive waste legislation in 1981:

1. What to do about final isolation of the highly radioactive waste produced by nuclear reactors, which is contained for the present in the spent fuel discharged by those reactors.
2. What to do with the growing inventories of that spent fuel now stored at the reactors, given the uncertainties about when (or even whether) it would prove worthwhile to reprocess them, and when final isolation facilities would be available.

Final Isolation

The central issue that was to be resolved concerning final isolation was how strong a commitment to make to the development of a waste disposal technology that, unlike storage, would not require continued human control and maintenance to assure safe isolation.[11] Some argued that a disposal system should be developed with all deliberate speed. Others argued that a long period of interim storage (many decades) should be planned before developing a disposal system so that more options could be made available and uncertainties about the economic value of spent fuel could be resolved before selecting a disposal techology for development. Still others argued that storage itself is a satisfactory approach to final isolation, so no disposal system is needed. Although DOE made a formal decision to proceed with the development of mined geologic repositories, this decision had not yet been endorsed by Congress, and a bill passed by the Senate in the 96th Congress contemplated extended storage in monitored retrievable storage facilities as an alternative to rapid development of a disposal system. OTA's analysis indicated that until there was a clear resolution of this issue in law, continued instability in the direction of the waste management program was possible.[12]

There was considerable disagreement over the degree to which the future use of nuclear power should depend on the development of an acceptable program for final waste isolation. Some argued that the United States should make no significant new commitments to nuclear power—and hence to the generation of more waste—until the safe and final isolation of nuclear waste could be demonstrated. Others argued that the technology for safe, final isolation was available and that there was no technical justification for restricting waste generation. Nonetheless, they argued that a demonstration of final isolation was needed to allay public concerns that threatened the continued growth of nuclear power. From either point of view, it was seen as important to resolve the existing uncertainties about final isolation of radioactive waste.

Even among those who agreed that developing the capability to dispose of—rather than store—radioactive waste was necessary to stop the issue from becoming an encumbrance on the use of nuclear power, there was substantial disagreement about how to demonstrate this capability and about the urgency of doing so. Some believed that the current basis of knowledge about mined geologic repositories was adequate to permit an acceptably safe repository to be sited and constructed quickly. They argued for rapid development of a repository (and perhaps an earlier unlicensed demonstration facility into which a small amount of waste would be emplaced) to allay what they perceived to be unfounded public concerns about waste disposal. Others believed that more time would be needed to develop sufficient confidence in a repository design and site. They contended that emplacement of waste in a demonstration facility would not by itself allay public concerns and feared that pressures for rapid action could lead to a premature commitment to an inadequate repository site or design or, at the very least, would lead to actions that would jeopardize the credibility of the Federal waste disposal program.

Some argued that resolving disagreements about the technical feasibility of waste disposal would not, in itself, be enough to remove disposal as an issue affecting the use of nuclear power. Demonstrating the Federal Government's *institutional* capacity to carry out the difficult effort required to build and operate a safe and reliable waste isolation system may be as important as demonstrating the *technical* capacity to dispose of waste.

Interim Spent Fuel Storage

The fact that neither reprocessing nor a Federal waste repository was likely to be available for a decade or longer meant that it would be necessary to provide interim storage for large quantities of spent fuel for at least the rest of the century. This posed two key problems for utilities, which led some to seek Federal assistance in providing that storage. First, reactors were running out of storage space, and it was clear that some might have to shut down by the mid-1990's unless more storage space were made available—even if existing basins were expanded as much as possible and if utilities were allowed to ship spent fuel to unfilled basins at other reactors.[13] Some utilities would face serious problems by the late 1980's if such shipment were not allowed. Because of the relatively long leadtimes needed for the construction and licensing of new storage facilities, these utilities needed to know within a few years whether they would have to provide such facilities themselves.

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[11] An extensive discussion of this subject is found in issue 1 of app. B.

[12] OTA testimony before the House Committee on Science and Technology, Subcommittee on Energy Research and Production, Oct. 5, 1981.

Second, the fact that there was no firm schedule for either reprocessing or turning spent fuel over to the Federal Government left the utilities completely in the dark about how much additional storage capacity they would have to provide, when they would be able to end their liability for the growing inventories of spent fuel, and how much the total cost would be for storing and disposing of that fuel. There was increasing opposition to efforts to provide additional storage capacity because of fear that easy availability of interim storage would reduce the pressures for developing a Federal disposal system, thus turning interim storage facilities into permanent waste repositories. This opposition, in turn, had increased utilities' fears that they might not be able to gain approval for additional storage facilities quickly enough to prevent reactor shutdowns.

Concern about the utilities' capacity to provide additional interim storage quickly enough to prevent reactor shutdowns, especially in the face of the Government's failure to develop disposal facilities, led some to argue that the Federal Government should provide away-from-reactor storage facilities to give utilities one sure way to get rid of spent fuel once their existing basins were full.[14] Others argued that the utilities should be responsible for interim storage, while the Federal Government concentrated on the disposal program. While the Carter administration proposed that the Federal Government acquire an away-from-reactor facility, the 96th Congress did not authorize it, and the Reagan administration focused, instead, on helping the utilities provide their own additional storage.

Complicating Factors

Linkage to Broader Issues

Resolution of disagreements about commercial waste management policy has been complicated by linkages to broader issues: the use of nuclear power, the future of reprocessing, and the disposition of high-level waste from defense activities. OTA's review of the history of waste management showed that disagreement over these broader issues was a major reason for the past inability of the Federal Government to devise a stable policy for dealing with commercial wastes, and suggested that successful adoption and implementation of such a policy would be easier if the policy were neutral regarding the resolution of these broader issues.

THE USE OF NUCLEAR POWER

In the mid-1970's, the public began to challenge the wisdom of developing a nuclear power industry unconstrained by the status of waste management. As noted in a memorandum for a JCAE policy session:

> . . . the uncertainties concerning the location of the repository are already adversely affecting public acceptance of nuclear power, and it is possible that this aspect of the overall nuclear program could become an unnecessarily important negative factor in the Nation's ability to consider its nuclear option to power generation.[15]

While there is strong disagreement about whether there should be any formal linkage in Federal law between progress in developing a final isolation program and the operation of nuclear reactors, there already is such a linkage in some State laws and in NRC policy. In 1976 California passed a law, upheld by the Supreme Court in 1983,[16] that made the siting of reactors in that State contingent upon Federal Government assurance that the demonstrated technology or means for disposal of high-level waste existed. In addition, the Natural Resources Defense Council petitioned NRC to conduct a rulemaking proceeding to determine if high-level waste could be disposed of without undue risk to the public health and safety and to refrain from licensing reactors until such a determination was made. In denying the petition, a position upheld in court, NRC stated that it "would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely."[17] In 1981 NRC announced its intention to conduct a generic proceeding "to reassess its degree of confidence that radioactive waste produced by nuclear facilities will be safely disposed of, determine when any such disposal will be available, and whether such wastes can be safely stored until they are safely disposed of." As a result of this "Waste Confidence" proceeding, NRC concluded in 1984 that there is reasonable assurance: 1) that safe disposal of high-level waste and spent fuel in a geologic repository is technically feasible, and 2) that one or more mined geologic repositories would be available in the 2007-2009 time frame.[18]

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[13] Such shipment between reactor pools is referred to as "transshipment."

[14] An extensive discussion of this issue is found in issue 4, app. B.

[15] App. A, p. 225.

[16] *Pacific Gas & Electric Co.* v. *State Energy Resources Conservation and Development Commission,* 1 U.S.L.W. 4449 (Apr. 20, 1983).

An analysis of the merits of proposals to limit the use of nuclear power pending progress on waste disposal involves questions of energy policy that are beyond the scope of this OTA study.[19] However, currently operating reactors, which have already discharged more than 10,000 tonnes of spent fuel, would generate around 55,000 tonnes by the end of their operating lives, even if no additional reactors were licensed for operation. The waste in this spent fuel must be isolated safely, regardless of the future of nuclear power. However, the nuclear waste problem is only one of a number of difficulties inhibiting the expanded use of nuclear power,[20] and resolution of that problem by itself may not be sufficient to sway decisions in favor of new reactor orders.[21] Nonetheless, if the other difficulties are resolved, it appears likely that the degree of progress in the final isolation program in the next decade could affect decisions about the future use of nuclear power, whether or not there is a formal linkage between the two subjects. If a policy can be adopted, maintained, and implemented steadily and successfully over an extended period it can be expected to have a positive effect on attitudes about nuclear power. Continued delays and shifts of direction, or discovery of major unforeseen technical problems, could have a negative effect on the willingness of utilities to invest in new reactors.

REPROCESSING AND THE POTENTIAL ECONOMIC VALUE OF SPENT FUEL

In OTA's view, the uncertainty about when, if ever, it will become economical to reprocess spent fuel has unnecessarily complicated Federal decisions about interim spent fuel storage and about final waste isolation. Some have argued, for example, that because spent fuel is a potentially valuable resource, the capacity to dispose of spent fuel need not—and should not—be developed until a clear decision on reprocessing is made. Extended or permanent storage has been proposed instead of disposal as a means of ensuring that the potential economic value of spent fuel is indefinitely preserved. However, the development of a disposal capacity will take more than a decade, and even when it is developed, spent fuel does not have to be disposed of irretrievably. Thus, the major decisions facing the 97th Congress did not concern the advisability of disposing of spent fuel, since the capacity to do so did not yet exist; rather, they concerned when and at what rate the capacity to dispose of waste would be made available, and what provisions would be made for the storage of spent fuel and any reprocessed waste in the meantime.

If the economic value of spent fuel remains uncertain once a disposal capacity has been developed, the decision can be made at that time whether to continue storing spent fuel or to dispose of it. As discussed in chapter 3, storage could be accomplished at a repository site by using the repository's packaging and handling facilities to receive and prepare waste for storage on the surface. Developing the capacity to dispose of both spent fuel and reprocessed waste may, in fact, be the best way to ensure that the decision to reprocess or dispose of spent fuel is based mainly on the resource value of the spent fuel and not on the lack of a capacity to dispose of either spent fuel or high-level reprocessed waste.[22]

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[17] App. A, p. 227.

[18] U.S. Nuclear Regulatory Commission, 10 CFR Parts 50 and 50, "Waste Confidence Decision," *Federal Register*, vol. 49, No. 171, Aug. 13, 1984, pp. 34658-34688.

[19] This issue was not addressed in the NWPA.

[20] *Nuclear Power in an Age of Uncertainty* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-E-216, February 1984). See also Graham Allison et al., "Governance of Nuclear Power" (Cambridge, Mass.: Energy and Environmental Policy Center, Harvard University, December 1981).

[21] Allison et al., op. cit., p. 43.

The question of when it might be desirable to dispose of spent fuel irretrievably, therefore, is quite distinct from the question of when it will be desirable to have the technical capacity to do so, although the two are frequently confused in discussions of waste management policy. The only irreversible decisions that can be made now are those related to the availability of technical capacity for disposal, since the longer the development of disposal facilities is deferred, the longer future waste managers will have no choice but to continue storage.

DEFENSE WASTE POLICY

The defense and commercial high-level radioactive waste programs, merged under the Carter administration, were separated by the Reagan administration. Disagreements about whether the same procedures for siting commercial waste repositories should also apply to repositories for defense wastes were a major reason the legislation dealing with high-level radioactive waste did not pass in the 96th Congress.

In this regard, some people argued that no matter what is done with military waste, the Federal Government had an obligation to get on with the resolution of the commercial waste management problem. They pointed out that the Government had, by law, reserved for itself the responsibility and the authority to dispose of high-level waste[23] and, thus far, had failed to fulfill its responsibilities. They argued that efforts to deal with commercial wastes should not be impeded by disagreements about policies for managing defense waste, as occurred during the 96th Congress. They also contended that separating the commercial and defense programs could allow more rapid progress in commercial waste disposal, which would, in turn, make it easier to deal with defense wastes by providing usable technology and sites. They noted that there were no compelling public administration arguments to have a single organization dealing with the two problems and cited precedents for separating military and civilian programs with similar technical requirements, such as assigning the civilian space program to the National Aeronautics and Space Administration. Moreover, some viewed a different institutional approach to siting repositories for defense waste as justified because they believed the balance of Federal authority should be greater in an activity associated with national defense.

Those who favored handling commercial and defense wastes in a unified program cited the similarities between their technical and environmental needs for long-term isolation. Such an integrated approach, they argued, would be necessary for gaining public acceptance of a national repository program and would discourage deferral of progress on disposal of defense wastes or the use of less stringent procedures in the defense program. Those who disagreed cited the fact that, since Federal law already provided that any repository for high-level waste, whether defense or commercial, would have to be licensed by NRC to meet the same environmental standards, separation of the programs would not necessarily lead to a less stringent approach with defense wastes.

Federal Credibility and Mutual Distrust

The most formidable problem that NWPA had to address was the intense level of mutual distrust among various concerned parties, a distrust that threatened to lock the waste disposal effort in a state of virtual and continual paralysis. The single most critical factor in that distrust was the severe erosion of public confidence in the ability of the Federal Government—on the basis of its past record—to create and carry out an effective waste management program.[24] The utilities and the nuclear industry doubted that the Federal Government would ever meet a schedule or stick to a policy. Environmentalists doubted that the Federal Government would deal adequately with safety concerns. States doubted that the Federal Government would deal openly and fairly with them.

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[22] This is discussed in issue 3, app. B.

[23] William C. Metz, "Legal Constraints on Repository Siting," *Nuclear Waste: Socioeconomic Dimensions of Long-Term Storage*, Steve H. Murdock, F. Larry Leistritz, and Rita R. Hamm (eds.) (Boulder, Colo.: Westview Press, 1983).

[24] National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal: Considerations for Institutional Management* (Washington, D.C.: National Academy Press, 1984), p. 38.

To the degree that a Federal law alone can do so, NWPA went a long way toward meeting many of the specific concerns of the various parties and toward strengthening the credibility of the Federal effort. Below is a brief discussion of the main reasons why the credibility of the Federal program was so low before the passage of NWPA and of some of the remaining problems of mutual distrust that could complicate the effort to implement the Act.

POLICY INSTABILITY

The Federal waste management effort had been plagued by many major shifts of policy, making steady progress difficult and undermining public confidence in the effort.[25] A major cause of policy instability had been the failure of the Federal Government to consider a broad enough range of viewpoints, or to address adequately the legitimate technical and nontechnical concerns of major interest groups. This left some groups with a strong incentive to try to thwart or change the policies.

As a result, changes in administration had often meant abrupt changes in waste disposal policy. In 1976, for example, President Ford responded to concerns about the need to demonstrate progress in waste disposal by announcing a 1985 target date for the first repository, a policy that led to an almost exclusive focus on salt as a disposal medium and on sites that had already been studied or were regarded as easy to secure. The Carter administration, responding to the resulting concerns that an accelerated schedule could lead to premature commitment to a medium or site, adopted a new policy involving the review of four to five sites in two to three media and an anticipated repository target date of 1997 to 2006. The Reagan administration abandoned the Carter policy for one of examining three sites in two media, the minimum requirements of NRC, with earlier development of demonstration facilities. With respect to interim storage, the Carter administration proposed that the Government acquire an away-from-reactor facility and offered to accept spent fuel from utilities for interim storage prior to disposal. The Reagan administration rescinded the offer and announced that utilities would be responsible for interim storage. In view of such shifts, some observers questioned whether any policy could be expected to outlast a change of administration.

FEDERAL CAPACITY TO IMPLEMENT A POLICY[26]

The history of the waste management program raised questions about the institutional ability of the Federal Government to implement any waste management policy successfully, even if the policy could be stabilized for an extended period. There were several reasons for this concern.

First, until the mid-1970's, the waste management effort was starved for the stable and sufficient resources—both people and money—needed to ensure a successful waste management effort. Not until 1972 did waste management exist as a distinct bureaucratic entity with its own independent budget, and not until 1977 did the program receive substantial funding. Increases in the number and expertise of the staff that the waste program needed to meet its responsibilities did not keep pace with increases in funds. Moreover, history suggested that the normal Federal budget process may not assure the adequate and stable long-term funding needed to enable timely development of final isolation facilities. For example, inadequate funding of the Federal Government's geologic repository development program had limited the number of alternative technologies and sites that were investigated, increasing the likelihood that an acceptable system would not be developed in a timely manner and heightening concerns about the technical adequacy of the program.

Second, past problems in the final isolation program had raised questions about the capabilities of the DOE waste management program. These questions will burden its future efforts, even though the problems reflected not the competence of the people carrying out the program, but the low priority placed on the effort, the lack of resources, and the sharp and frequent shifts of policy. Although generally regarded as technically competent, the DOE program did not appear to have enough people with the skills needed to handle the social, political, and institutional issues that concern States, local communities, and groups outside of DOE or to handle the broad policy and strategic issues. The failure to go beyond the strictly technical questions and address these kinds of issues had undermined much of the credibility of the waste management program.

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[25] The State Planning Council recommended that "national planning for radioactive waste management should avoid abrupt changes in direction to prevent further deterioration of program credibility and loss of time." State Planning Council on Radioactive Waste Management, *Recommendations on National Radioactive Waste Management Policies: Report to the President*, 1981, p. 29.

[26] These issues are discussed at greater length in ch. 7.

Finally, the development and implementation of a comprehensive waste management policy will require an unprecedented degree of coordination within both the executive branch and Congress. At present, no single Federal agency or congressional committee has the jurisdiction to deal with the wide range of activities required to manage radioactive waste safely. Six major executive agencies and about 12 congressional committees have jurisdiction over different aspects of waste management. Experience suggests that coordinating the activities of all these Government entities will be difficult. Also, agencies have consistently failed to meet deadlines to implement policies according to schedule, perhaps, in part, because waste disposal is only one of the many activities for which they are responsible. For example, NRC's draft technical regulations for high-level waste, scheduled for issue in 1977, were actually issued in 1981; EPA's overall standards for waste disposal, due since 1977, were not even published for discussion until the end of 1982. These delays have raised questions about the ability of the Federal Government to meet a long-term schedule requiring the coordinated actions of independent agencies.

PERCEPTIONS OF TRUSTWORTHINESS

Justified or not, States and others had developed strong doubts that the Federal Government could be counted on to keep its word on waste management matters and that, in general, it could be trusted. One example of the basis for this distrust is the series of policy reversals concerning WIPP discussed above.

State Concerns[27]

To make technical progress in waste disposal, the Federal Government must have access to potential disposal sites in order to perform the detailed study and evaluation needed to determine site suitability. However, several States have sought to prevent DOE from conducting initial site investigations, and 18 States have enacted restrictive legislation that bans high-level radioactive waste management activities within their borders without State approval.[28] Other States may feel obligated to adopt similar restrictions to make certain they do not, by default, end up with waste storage or disposal facilities.

In addition to general concerns about Federal trustworthiness, State opposition to Federal siting activities has two main sources:

- *The Inherent Costs and Risks Involved in Waste Disposal.*—The presence of any amount of radioactive waste and the various steps involved in storage and disposal pose potential radiological risks and have adverse social and economic impacts on States and localities. Although these impacts can be controlled or mitigated, there is no assurance that they can be eliminated. Even if States had no other concerns about waste disposal, they would probably be reluctant to take on such costs and impacts. In its extreme form, the desire not to bear the costs involved in waste disposal can lead to what has been called the "not in my backyard" or "anywhere but here" attitude, which may underlie at least some State opposition.
- *Fear of Unfairness in Siting Decisions.*—Many States fear that they could become a national dumping ground for waste—that they will be forced to take waste generated in other States or even from the entire Nation, thus bearing a disproportionate share of the waste disposal burden. Related to this fear is that of the "foot in the door"—the concern that if the Federal Government succeeds in siting any waste management facility, even a small research facility, it will try to save money and avoid fighting new siting battles by attempting to expand that facility, eventually creating a repository at that site. A related State fear is

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[27] State issues are discussed at greater length in ch. 8.

[28] Sarah Daneman, "State Legislation on High-Level Nuclear Waste Disposal (as of 9/15/82)," published in *The Radioactive Exchange*, vol. 1, Nos. 14 and 15, Part II, September/October 14, 1982, pp. 15-21. Some laws have banned activities involving waste from other States; others have required State approval prior to storage or disposal of all commercial high-level waste. DOE has so far not challenged the legality of these restrictions in court.

> that Federal siting decisions will be based too heavily on considerations other than technical safety criteria, such as a desire to site a repository quickly to remove waste disposal as an obstacle to the use of nuclear power or a desire to avoid the difficulties of dealing with restrictive State legislation.

Although restrictive State legislation may not stand up to Federal court challenges, the legal processes entailed in such challenges could delay siting efforts. DOE had been reluctant to contest State restrictions and had sought, instead, to conduct waste management activities at sites where it was likely to encounter the fewest obstacles—either in time, cost, or political opposition. That approach can be defended on the grounds that, if it speeds up the process, and if the site eventually selected is technically sound, then it matters little how the site is chosen. However, that approach may increase resistance to Federal siting activities for two reasons. First, no site selection process is likely to be perceived as equitable or technically credible if it chooses, or appears to choose, sites mainly because they are the easiest to obtain. Second, the approach feeds State fears that the Federal Government will increasingly follow a "path of least resistance" in seeking repository sites and thus strongly encourages those States that have not yet adopted restrictive or prohibitive measures to do so. No State wants to be last in the race to make certain that the path of least resistance does not lead straight into its borders.

Overall Impacts of History

NWPA is the first Federal law that sets out an explicit national policy and schedule for the disposal of high-level radioactive waste. It also contains a number of provisions aimed at overcoming some of the major concerns that have hampered the waste disposal effort in the past. But a law alone, no matter how well framed, cannot by itself wipe out the long legacy of problems and false starts and the deep distrust it has generated among the principal parties involved and concerned with waste disposal.

A law alone cannot demonstrate that the Federal Government has the capacity to deal fairly with the States in the selection and development of sites, to take the surest and safest route to waste disposal instead of the most expedient, or to demonstrate to the satisfaction of the regulatory authorities and the concerned and affected parties that an adequate waste disposal technology exists. Nor can a law alone dispel, however much it may allay, the distrust that decades have built up among the various parties.

That distrust may, indeed, be the single most complicating factor in the effort to develop a waste disposal system that is acceptable technically, politically, and socially. For, if Federal credibility—its capacity to show the various parties that it can and will do the job competently, fairly, and on schedule—remains the most critical factor in a successful waste disposal effort, it is not Federal credibility alone that is in question. States, environmentalists, and others may, indeed, fear that the Federal Government and industry will cut corners just to be able to say that the problem is solved. But there is the correlative concern that not all State forces or environmentalists are acting in good faith: that, whatever their express concerns with safety or other matters, some environmentalists seek to block and stall waste disposal efforts solely because they are opposed to the use of nuclear power, and some in the States seek only to prevent any and all waste disposal activities from occurring within their borders.

In short, some believe that no matter how well the Federal Government does its job in carrying out the Act—no matter what pains it takes to remove any legitimate grounds for opposition—there are those in the States and elsewhere who will do everything possible to slow or stop its efforts. Whatever the basis for this belief, it only makes it all the more necessary for the Federal Government to remove the legitimate grounds for opposition by carrying out the Act in ways that address the honest concerns of States and others and that seek to avoid past mistakes.

The waste management program has improved substantially over time in resources, breadth of organizational commitment, and technical and institutional sophistication. It has laid a solid technical groundwork for the development of mined geologic repositories. Furthermore, resolution of the key policy issues regarding interim storage and final isolation through enactment of NWPA should provide stability to waste management policy that has been lacking in the past. Nonetheless, the burden of past problems will complicate the task of developing an effective and acceptable waste disposal system. Moreover, after more than three decades of struggling with nuclear waste, there is only a limited tolerance for failures. Any major failures—real or perceived—could have grave consequences for both the waste management program and the future use of nuclear power.

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Chapter 5

Policy Analysis: The Nuclear Waste Policy Act of 1982 in Perspective

The issues and problems described in the preceding chapter were debated extensively during the 96th and 97th Congresses, culminating in final passage of the Nuclear Waste Policy Act of 1982 (NWPA) in the closing hours of the 97th Congress. During the course of that debate, OTA presented the principal results of its study of commercial high-level radioactive waste management to Congress through testimony and release of a summary report that dealt with the key issues under debate.[1] As part of its study, OTA analyzed a wide range of views from the technical community, Federal agencies, the nuclear industry, the environmental community, State and local officials, and the lay public. OTA then identified the basic elements of a waste management policy that addressed the main concerns of the major affected parties. Thus, while OTA examined a wide range of issues and options as part of its assessment, it focused its testimony and report on that particular combination of options that appeared capable of securing the credibility, stability, and broad support essential to a successful waste management effort. This chapter contains the basic policy conclusions underlying that integrated policy, the key elements of that policy, and an analysis of NWPA from the perspective of that policy. Many of the points summarized in this chapter are discussed at greater length in the following chapters. Discussions of the principal technical issues addressed in NWPA are found in appendix B, and the full text of the Act is included in appendix C.

KEY ELEMENTS OF A COMPREHENSIVE POLICY

The fundamental finding that OTA presented to Congress was that, if history were not to repeat itself, and if the stalemate on nuclear waste were not to continue, a comprehensive policy was needed that commanded the support and addressed the concerns of all major interested parties, made a formal Federal commitment to developing several disposal facilities according to a firm and conservative schedule, and guaranteed the financial and managerial resources required to meet that commitment.

By 1980 a widespread concern had developed that the Federal Government could not or would not manage radioactive waste safely and efficiently. The doubts concerned not so much the technology of disposal as the institutional capacity of the Federal Government to carry out the difficult and sustained effort required to build and operate a disposal system that could safely handle large amounts of waste. The long-term uncertainties and strong doubts about the Federal Government's capacity to cope with the nuclear waste problem were the main obstacles to the waste management effort. Only a comprehensive policy that focused on solving the final isolation problem and that addressed institutional as well as technical issues appeared likely to overcome those doubts and uncertainties.

Such a policy, moreover, had to be both acceptable and credible to all concerned parties. For unless all parties supported a given policy—or at least had a strong stake in seeing it succeed—the policy instability of the past was likely to persist, with each new administration changing the policy of its predecessor in order to satisfy one interest group or another. Thus, the more a waste management policy represented a formal agreement—a genuine treaty that all sides could accept because it addressed their interests and concerns and because they believed it could work—the more likely that policy would be to survive changes of administration and to avoid extensive judicial and other delays.

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[1] Office of Technology Assessment, *Managing Commercial High-Level Radioactive Waste*, April 1982.

OTA concluded that to be credible, a waste management policy had to adopt a conservative approach that carefully identified all the potential sources of technical and institutional failure, took the steps necessary to keep the risk of failure to a minimum, and included contingency plans for dealing with any failures that did occur. In addition, because of the high level of distrust of the Federal waste management program, credibility required a high degree of explicitness about and commitment to key policy measures and programs for carrying them out.

The radioactive waste management policy that OTA concluded would be both broadly acceptable and credible would contain three main elements, each of which would be aimed at overcoming one of the three major obstacles to a successful Federal waste management effort: 1) policy instability; 2) doubts about the institutional capacity of the Federal Government to implement a long-term policy; and 3) perceptions of a lack of Government trustworthiness.

Element I—Commitment in law to the main goals of a comprehensive national policy for interim storage and final disposal of commercial high-level radioactive waste:

A. To develop several final disposal facilities—mined geologic repositories—on a firm and conservative schedule.

B. To contract with utilities to begin accepting waste at a repository on a conservative date, when a repository is likely to be available.

C. To assist the interim storage efforts of utilities by supporting licensed demonstrations of dry storage technologies, and by providing a limited amount of supplemental storage capacity as an emergency backup in case of unavoidable delays in utilities' efforts to develop their own storage capacity.

Element II—Credible institutional mechanisms for meeting the policy goals:

A. Congressional approval of a binding Mission Plan,[2] developed by the administration, that spells out the technical and institutional actions and the financial and managerial resources required to meet the policy goals.

B. Assured funding through a waste management fund financed by a mandatory user fee based on the Mission Plan and paid by utilities at the time the waste is generated.

C. Assurance of adequate managerial resources through creation of an independent, single-purpose agency whose sole responsibility is to carry out the waste management program.

Element III—Credible measures for addressing the specific concerns of the States and the various publics:

A. Development of explicit plans and provision of assured funds for involvement of the lay and technical publics.

B. Development of a regulatory process that makes ample allowance for the first-of-a-kind nature of the problem of demonstrating that a disposal system will provide the desired degree of isolation for millennia.

C. Provision in law of measures dealing with State and local concerns, such as a formal role in repository siting decisions and impact compensation.

The technical and institutional elements of the policy outlined above are all mutually supportive and, in several respects, inseparable. For example, unless the policy is carried out by a single-purpose organization with assured and adequate funding, no comprehensive program that attempts to follow a firm schedule over a long period of time is likely to have much credibility with the general public or with the utilities. Similarly, it may be possible to gain broad support for a single-purpose organization with independent funding only if effective oversight mechanisms are assured and if there is substantial agreement in advance, laid out in a Mission Plan, about precisely what the organization is going to do and how it is going to do it.

Because of these interdependencies, several stages may be required to implement all of the elements of the policy. OTA viewed the radioactive waste management problem as a nettle that, painful as it might be, would have to be grasped in its entirety if it were ever to be resolved.

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[2] In OTA's 1982 summary report, *Managing Commercial High Level Radioactive Waste,* the term Management Action Program was used for this concept. However, since NWPA uses the term Mission Plan, this report has adopted that terminology.

THE NUCLEAR WASTE POLICY ACT OF 1982

The passage of NWPA represented a watershed in the development of Federal waste management policy. This section describes and analyzes the major provisions of NWPA, using the integrated waste management policy outlined above as a framework, and identifies the key issues that remain to be resolved.

Element I:

Commitment in law to the main goals of a comprehensive national policy for interim storage and final disposal of commercial high-level radioactive waste.

By including measures to deal with both interim storage and final isolation, NWPA addresses both the concerns of utilities facing the near-term need for additional spent fuel storage and the concerns of those who feel that the highest priority must be given to the long-term task of a developing final isolation system for high-level radioactive waste. The embodiment of an explicit high-level radioactive waste management policy in law demonstrates that Congress as well as the administration is committed to the policy, a fact that should help ensure the policy stability that has been lacking in the past.

OTA's analysis concluded that comprehensive waste management legislation should commit the Federal Government to three basic policy goals:

Goal 1: **To develop several final disposal facilities—mined geologic repositories—on a firm and conservative schedule.**

Permanent Disposal Facilities.—NWPA resolved the dispute about whether to proceed with long-term storage or permanent disposal by adopting as its primary focus a requirement that the Federal Government site, construct, and operate facilities for the permanent disposal of high-level waste and any spent fuel disposed of as waste.[3] The history of strong and successful opposition to proposals to develop Federal storage facilities for commercial radioactive waste suggests that the development of permanent disposal facilities is required to satisfy public concerns about waste disposal and to serve as the basis for a widely accepted and stable waste management policy. Unlike storage, disposal does not place a burden of continued care and maintenance on the future, and it is less vulnerable to carelessness or neglect by some future generation. Moreover, a commitment to develop disposal facilities provides future generations with a greater range of choices than would storage alone. Such facilities will give waste managers the option of disposing of spent fuel or high-level reprocessed waste, or of deferring disposal by placing any such material delivered to a repository into extended storage at the surface. The development of facilities that can handle both reprocessed waste and spent fuel will also ensure that waste management efforts are not impeded by debates about reprocessing.

At the same time, NWPA ensures that long-term storage will be available as an option by requiring the Department of Energy (DOE) to prepare a detailed proposal for construction of one or more monitored retrievable storage (MRS) facilities and an analysis of the need for such facilities to be presented to Congress for consideration by July 1985. However, it also requires that disposal in a permanent repository proceed regardless of whether any MRS facilities are constructed. The question of the role of MRS facilities in the overall waste management program remains to be resolved, as discussed in the following chapter.

Mined Geologic Repositories.—NWPA does not simply commit the Federal Government to develop permanent disposal facilities; it also lays out a detailed process for siting and licensing one particular permanent disposal technology—the mined geologic repository. (This process is outlined in app. E.) The mined geologic repository is the clear choice as the disposal technology to be developed because it is the most thoroughly studied technology and is most widely favored by the international technical community. Both the technology and the required regulations exist or are being developed, and available analyses indicate that a licensed geologic repository could be developed within the next 20 years if adequate resources are devoted to the task. The legislated commitment to develop geologic repositories both demonstrates and promotes policy stability, since it involves no change in direction from previous programs and policies.

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[3] An extended discussion of this dispute is found in issue discussion 1 of app. B.

Unlike subseabed disposal (the most promising alternative disposal technology), disposal in mined geologic repositories in the continental United States does not raise the question of the need for international agreements for access to disposal sites. In any case, development of mined repositories will not preclude development of other disposal technologies and a later decision to use one that proved to be sufficiently attractive; in fact, NWPA requires DOE to accelerate research and development (R&D) of alternative technologies for permanent disposal. If another technology were chosen later, any geologic repository sites that had been developed by then could still be used for supplemental purposes, such as disposal of waste forms (e.g., transuranic-contaminated [TRU] wastes) that might be too bulky for disposal using other technologies.

Several Repositories.—NWPA includes mandatory schedules for siting and licensing two separate geologic repositories, with a site for the second to be selected within 3 years of the first. There are three main advantages to developing several repositories more or less in parallel instead of developing and filling one repository at a time. First, a waste management system with two repositories would be more reliable, since disposal operations could continue at one even if problems arose that interrupted loading or limited the total disposal capacity of the other. Second, if acceptably safe, licensable sites can be found in the East near the majority of existing and projected reactors, the costs and risks of waste transportation—as well as the number of communities affected by it—would be substantially less than those of a system based on a single repository in the West, where most sites now under consideration for the first repository are located. Recognizing this, NWPA explicitly requires transportation impacts and costs to be considered in selection of the site for the second repository. Third, a system with two repositories is more equitable and could allay the fears of any State that it might become the Nation's sole dumping ground for nuclear waste. Thus, siting two repositories may encounter less political opposition than an effort to develop only the single site of a centralized system.

Full realization of these advantages requires that the second repository begin operating within a relatively short time after the first. While NWPA requires the first repository to begin operating by early 1998, there is no explicit target date for operation of the second. To ensure that a second repository ultimately is developed, NWPA prohibits emplacement of more than 70,000 tonnes of spent fuel in the first repository until the second begins operating. While this limit exceeds the 55,000 tonnes expected to be discharged by the reactors that are now in operation, it is considerably less than the total of about 100,000 tonnes that will be produced if the reactors now under construction are completed. Thus, the limit in NWPA is likely to require eventual construction of the second repository. However, its operation could be deferred for up to perhaps 20 years after emplacement of waste begins in the first.

To avoid strong budgetary pressures to continue to expand the first licensed repository and to defer the financial and political costs of developing a second one as long as allowed by the Act, the development of a regional system may require an explicit commitment by DOE to begin operating a second repository within a specified time after the first is operational. The time should be short enough to give credibility to the commitment, but long enough to allow the development of the second repository to benefit from the lessons learned in siting and licensing the first. To give additional credibility to the commitment, and to assure the availability of resources as needed, the actions needed to develop and operate the second repository on schedule should be included in the Mission Plan (Element II-A), and the additional costs should be considered in determining the revenues required from the disposal fee (Element II-B). (Further discussion is found in the following chapter.)

A Firm and Conservative Schedule.—A central provision of NWPA is the requirement that DOE begin disposal of radioactive waste in the first geologic repository no later than January 31, 1998. Prior to passage of the Act, the repository schedules used by DOE and its predecessors lacked the force of law, and repeated slippages had called into question the credibility of Federal assurances that a repository would be available within a reasonable period.

A major conclusion of OTA's assessment was that such a commitment in law to a firm schedule for operation of a geologic repository was central to a resolution of the radioactive waste problem. It was needed to provide:

1. *Assurance that a permanent disposal system that does not place a burden of continued care and maintenance on future generations will be developed within a reasonable period of time.* Any extended delay in the development of disposal facilities would deeply concern both those who wish to remove the waste problem as a burden on the continued use of nuclear power, and those who fear that interim storage would become a permanent solution by default.
2. *Clear and fixed goals for an implementation program.* Long-term planning is difficult in the absence of well-defined and agreed-upon program goals, which had been lacking in the past.
3. *A firm basis for planning interim spent fuel storage.* Without a repository schedule, the utilities' storage problem would remain open-ended.

For the commitment to a firm schedule to be most credible, the target date for beginning operation of the first repository should be a conservative date that makes ample allowance for the reality that the location, design, and licensing of a geologic repository is a complex endeavor that has never been done before and that, therefore, no one knows for certain how long it will take. OTA's analysis suggests that the most important aspect of securing and sustaining the public's and utilities' confidence in the waste disposal program is not how quickly a repository can be made available if everything goes right the first time, but whether the repository will be available according to a firm schedule that is widely accepted as feasible and reasonable despite the remaining technical and institutional uncertainties about the siting process.[4]

Whether the January 31, 1998, target date for initial operation of the first repository can be seen as conservative in this sense depends to a considerable extent on the approach to constructing and operating the repository that is adopted by DOE, as discussed at greater length in the following chapter. DOE analysis shows that the 1998 target date is very optimistic if initial operation must await construction of the packaging facilities of the repository.[5] However, if initial operation of the repository is achieved by emplacement of a small amount of waste packaged elsewhere as part of packaging and handling tests during the research, development, and demonstration (RD&D) program, as suggested in chapter 6, the 1998 target appears to be achievable even if there are delays in the siting and licensing process. (This assumes that a suitable site can be found among those now under consideration for the first repository; if none of these is licensable it appears unlikely that the 1998 deadline could be met.) As discussed further in chapter 6, an approach to repository development using an initial demonstration phase of small-scale operation, analogous to low-power operation of a reactor, could minimize the risk of failure to meet the mandated target date and could, at the same time, allay concerns that corners might be cut in order to meet the deadline.

***Goal 2:* Contract with utilities to begin accepting waste at a repository on a conservative date, when a repository is likely to be available.**

NWPA requires DOE and the owners of spent fuel and/or high-level waste to execute, by June 30, 1983, contracts under which DOE will accept and dispose of such material. A standard contract was promulgated by DOE in April of 1983,[6] and contracts have been signed as required by law.

NWPA does not require that the contracts specify delivery dates for the material that is covered, and the contract form adopted by DOE does not require DOE to publish a priority ranking for accepting spent fuel until 1991, or to approve utility delivery schedules until 1992, at the earliest. To give utilities that must make decisions about interim storage measures before 1992 a firmer basis for planning, the Mission Plan required by the Act would need to include an explicit contractual waste acceptance schedule and a clear statement of priorities for accepting waste.

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[4] An extended discussion of the repository schedule is found in ch. 6, and in issue 2 of app. B.

[5] U.S. Department of Energy, *Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 1984, pp. 3-A-27— 3-A-43.

[6] 10 CFR, Part 961.

Because the one geologic repository authorized by NWPA is the only facility that DOE is now authorized to construct where spent fuel or high-level waste could be accepted on a large scale, confidence that spent fuel will ultimately leave reactor sites depends largely on confidence in the program for siting and operating the first repository. Thus, the heart of the waste acceptance plan is a *repository loading schedule*—a target schedule for moving waste to geologic repositories. In order to provide a credible basis for contractual commitments with utilities and to assure communities near reactors that reactor sites will not become de facto long-term waste repositories, the *certainty* of the repository loading schedule is more important than the speed. To give greater certainty, the Mission Plan would need to contain a repository schedule that is a high-confidence prediction of when repositories are likely to be operating at a full-scale rate comparable to the rate of waste generation, despite the kinds of delays that might be anticipated. To avoid raising false expectations, this "best estimate" schedule would need to be clearly distinguished from more optimistic management goals that show the earliest that spent fuel could be delivered to Federal facilities if all goes well.

OTA's analysis concludes that if an expanded repository siting program (discussed in ch. 6) is used, there can be considerable confidence that the full-scale loading facilities of the two repositories required by NWPA could be operating no later than about 2008 and 2012, respectively, even if difficulties are encountered. This is a conservative estimate because it could be met even if all of the sites initially evaluated are rejected and a new backup site must be used for each repository. If such contingencies do not arise, the repositories could be available earlier. Even if the repositories do not operate at full scale until 2008 and 2012, they could still allow spent fuel to be removed from practically all reactor sites within 10 to 15 years after the expected date of reactor decommissioning. Further discussion of a conservative repository loading schedule using 2008 and 2012 as targets for contractual commitments to full-scale operation of two repositories is found in chapter 6.

Since unforeseen events could cause slippage in the repository loading schedule, even if the schedule included allowances for some delays, explicit provisions are needed for what would be done with waste until it can actually be delivered to a repository. As discussed below, NWPA provides that the utilities have the primary responsibility to provide for, and pay the costs of, interim storage until the material is accepted by DOE for disposal in a repository. The Act does not authorize DOE to construct any large-scale storage facility that could accept a significant quantity of waste before a repository is available.

A major question to be resolved is whether and how the waste management program should take responsibility for spent fuel storage if a repository is delayed beyond the 1998 target date contained in the Act. An extended discussion of this question is found in chapter 6. To summarize briefly here, the Mission Plan should contain provisions for two possible cases of delay in the repository program: relatively small and more or less expected delays in full-scale loading that entail additional interim storage beyond 1998; and large delays (decades or more) resulting from the discovery of now-unexpected problems with geologic disposal that could call into question its feasibility. The former possibility requires a *post-1998 interim storage plan*, which discusses who is to be responsible for the storage (the individual utilities with the immediate storage needs or the waste management program funded by all the utilities) and where storage is to occur (at the reactors or in a centralized MRS facility). The latter requires a *backup facility plan*—a plan for providing alternative storage (MRS) or disposal facilities if geologic disposal cannot be implemented in a reasonable time. These possible roles for MRS facilities also need to be evaluated in detail in the MRS need and feasibility study required by NWPA.

Goal 3: **Assist the interim storage efforts of utilities by supporting licensed demonstrations of dry storage technologies, and by providing a limited amount of supplemental storage capacity as an emergency backup in case of unavoidable delays in utilities' efforts to develop their own storage capacity.**

NWPA incorporates these provisions in their entirety.[7] Utilities are given primary responsibility for providing interim spent fuel storage capacity—including new storage facilities—until the spent fuel can be accepted by DOE for delivery to a repository. DOE is to aid utilities in developing the needed additional capacity through cooperative licensed demonstrations of new dry storage technologies. Cooperative agreements have been signed with three utilities for such demonstrations. DOE is also authorized to conduct dry storage R&D activities to provide data to assist utilities in licensing new storage facilities. In addition, NWPA includes measures to facilitate NRC licensing of new storage technologies and storage facility expansions.

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[7] An extended discussion of interim storage is found in issue 4 of app. B.

As a backup to utility efforts, DOE is directed to provide up to 1,900 tonnes of storage capacity on an emergency-only basis to utilities that are unable to provide their own storage capacity in time to prevent shutting down a reactor. NRC is to determine which utilities qualify to use that capacity. DOE can provide the storage either at existing Federal facilities or at reactor sites (using mobile storage equipment such as casks, or new facilities constructed at the site). The full costs of such storage are to be recovered through fees paid by the utilities using the storage.

Utility responsibility for interim storage will allow DOE to focus its attention on the disposal program and to avoid possible confrontations with host States and localities about efforts to obtain or construct a Federal interim storage facility. It should also reduce concerns that the availability of such a facility might undermine incentives for progress in the disposal program. The Act's strong Federal initiatives to promote commercialization of new and flexible dry storage technologies are needed to ensure timely resolution of licensing uncertainties that make such technologies a riskier prospect for utilities than the less attractive but more certain option of the water basin. Provision of a limited amount of emergency backup storage capacity should alleviate utilities' concerns about vulnerability to reactor shutdowns in the event of unavoidable delays in the provision of additional storage capacity. In addition, NWPA's commitment to a firm repository schedule should reduce the resistance to utility efforts to provide interim storage that has been based on concerns that such storage might become permanent by default.

Because of the promise shown by new storage techniques—rod consolidation (which increases the capacity of existing reactor basins) and dry technologies such as storage casks—the demand for such emergency backup capacity could be quite small. While no analysis of the precise amount of emergency storage needed is available, it can be noted that only 1,000 tonnes of storage would allow all of the 27 reactors projected to need new storage capacity by the end of 1989 an additional 2 years to provide that capacity.[8] DOE currently expects that the increased efficiency of at-reactor storage that is expected to result from demonstrations of rod consolidation and dry storage technologies should be sufficient to preclude need for any Federal interim storage.[9] Thus it now appears that utilities will be able to provide the needed additional storage capacity in time to prevent disruption of reactor operation.

Element II:
Credible institutional mechanisms for meeting the policy goals.

The basic institutional conclusion of OTA's review of the history of the Federal waste management effort was that substantial changes in the Federal Government's management approach would be needed to give credibility to the central component of Element I—the commitment to the development and operation of a complex technological system, faced with technical and institutional uncertainties, on a firm schedule over a period of decades. NWPA included many of the most important institutional changes that were included in the integrated waste management policy identified by OTA, although certain key issues were not addressed at the time the Act was passed. The provisions of NWPA are discussed below in the context of the three key institutional provisions of the integrated policy.

A: Congressional approval of a binding Mission Plan, developed by the administration, that spells out the technical and institutional actions and the financial and managerial resources required to meet the policy goals.

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[8] See issue 4, app. B.

[9] DOE, op. cit., p. 3-D-7.

NWPA requires DOE to submit a detailed Mission Plan to Congress, although no provision is made for formal congressional approval. The Mission Plan is needed to perform two key functions.[10] First, it must lay out a long-term waste management program, based on the authority in the Act, that fills in those details of the operation of the high-level waste management system that are not specified in the Act; that is, a repository loading plan, a post-1998 interim storage plan, and a backup facility plan.

Second, it must present an implementation program that DOE believes will be sufficient for achieving the goals of the waste management plan. A credible commitment to a long-term plan requires a credible implementation program for effecting it. To be credible in the face of the history of problems and delays in past Federal waste management efforts, an implementation program must identify the major possible sources of technical and institutional failure, provide measures that minimize the likelihood that these failures will occur, and include contingency plans for dealing with those failures that do occur. Such a program will likely involve an expansion of ongoing DOE programs to ensure that backup sites and technologies are available with minimum delay if problems develop with the principal candidates.

While a sound technical implementation program is necessary to the success of the waste management program, it may not by itself be sufficient because of the many institutional challenges that must also be met in siting and operating waste management facilities. Thus the Mission Plan should also contain an institutional implementation program showing how the activities of all the involved Federal agencies will be coordinated; how DOE will carry out the NWPA's many requirements for interactions with States and Indian tribes; and how DOE will provide for peer review of the technical programs and for public involvement (discussed below).

This comprehensive waste management plan and implementation program is needed to build confidence that the goals of the Act can and will be achieved, to provide a basis for estimating the resources needed to do so, and to pinpoint clear milestones that can be used to hold the responsible agencies accountable for timely progress.

OTA's study concluded that formal approval of the Mission Plan is a key issue to be addressed in any future congressional consideration of possible changes in the institutional arrangements for the waste management program, because the Mission Plan could play a central role in oversight and control of an independent waste management agency (discussed further below). Congressional approval would put teeth into the milestones in the Plan and would demonstrate congressional commitment to the Plan. Approval of the Plan on a multiyear basis would also give Congess a way to exert long-term control over the waste management program while allowing it the independence from the annual budget and policymaking process needed to ensure steady progress.

Without a formal mechanism for approving the Plan, there could be great value to developing a Mision Plan that is as broadly supported by the key interested parties as possible. Finally, the initial Mission Plan should include explicit provisions for further revisions of the Plan as required by developments during the implementation of the program.

B: **Assured funding through a waste management fund financed by a mandatory user fee based on the Mission Plan and paid by utilities at the time the waste is generated.**

Stable, adequate funding is essential if the Federal commitment to a firm schedule is to be met. The traditional annual budget and appropriations process appears inconsistent with such a commitment, since it lays great stress on keeping immediate costs as low as possible and thus will tend to cut back on the expanded aspects of the implementation program (e.g., development of backup sites and technologies) that are vital to building confidence that the target date can be met.

Prepaid Fee.—A major institutional provision of NWPA is creation of a Nuclear Waste Fund financed by a fee initially set at 1 mill (0.1 cent) per kilowatt-hour on nuclear-generated electricity.[11] Shifting the front-end funding of the waste management program directly to utility ratepayers at the time the waste is generated provides a large and stable source of funds, independent of annual competition with other Federal priorities. This should allow implementation of the expanded and more expensive program needed to give confidence that steady progress can be maintained over a period of decades. This arrangement also puts the total costs of waste management on the users of nuclear electricity rather than on the Federal taxpayer.

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[10] The Mission Plan is discussed in detail in ch. 6.

[11] Funding is discussed at length in ch. 7.

NWPA requires the Secretary of Energy to review the fee annually and to adjust it as needed to ensure that the full costs of the program are recovered. This provision allows funding levels to be determined by the program needed to meet desired goals, rather than having the achievable goals limited by the availability of funds, as occurred in the past.

Assured funding requires not only a reliable source of revenues, but also assurance that the funds will be made available to the waste management agency as needed to carry out the program. Thus, any future deliberations concerning the institutional arrangements for waste management need to consider ways of providing greater budgetary independence than is now the case under the Act, which continues annual appropriation control over the Nuclear Waste Fund. Greater independence, with continued congressional control, could be obtained through multiyear appropriations based on an approved Mission Plan, rather than through annual appropriations. This is discussed further in chapter 7.

C: **Assurance of adequate managerial resources through creation of an independent, single-purpose waste management organization whose sole responsibility would be to carry out the waste management program.**

Need for a Single-Purpose Agency.—The assurance of adequate management resources is as important as the assurance of adequate funds. For this reason, NWPA established within DOE a single-purpose Office of Civilian Radioactive Waste Management, whose sole task is to implement the provisions of the Act. The office, which is separate from the other nuclear activities of DOE, is headed by a Presidential appointee who reports to the Secretary of Energy. This step should stabilize the waste management organization at a higher policy level, insulate it from competition with other nuclear policy areas or future Federal reorganizations, and help provide the degree of central, integrated planning and management capability needed to meet a long-term Federal commitment on schedule.

NWPA also set in motion a process to ensure that institutional questions are addressed in more detail in the future by requiring DOE to submit to Congress a report on alternative institutional approaches for managing the radioactive waste program, including the option of establishing a private corporation. OTA's analysis of the history of the Federal radioactive waste management program concludes that the credibility of the central component of NWPA—a commitment to the development and operation of a complex technological system, faced with technical and institutional uncertainties, on a firm schedule extending over a period of decades—could be enhanced by the establishment of an independent waste management agency with more funding and management flexibility than is usual with a typical Federal program. The creation of such an agency may be the best way to ensure that other fiscal or political priorities of the Federal Government do not adversely affect progress in the waste management program.[12] Because the program is now funded entirely by fees paid by utilities for disposal services, rather than by appropriations from general Federal revenues, any additional costs involved in establishing and operating a new, single-purpose agency would be borne by the users of nuclear power rather than by the Federal taxpayer.

Establishment of an Effective Oversight Process.—The more independent an institution and its funding are, the surer the guarantee that a comprehensive program will be carried out on schedule. But such an institution raises a crucial and difficult question: how to ensure the congressional oversight and public accountability that a democratic society demands. *Achieving an acceptable balance between independence and accountability will be one of the central challenges in designing an independent waste management authority.*

As noted earlier, a major conclusion of OTA's study is that congressional approval of the Mission Plan could play a central role in achieving that balance. In fact, OTA's analysis suggests that it may not be possible to gain broad support for the creation of an independent institution with independent funding *until* a generally accepted Mission Plan has been developed. If decisions about an institutional structure (including the oversight mechanism) are made after the Mission Plan has been submitted, the decision about the appropriate degree of independence for such an institution would be made in light of an explicit agreement about precisely what that institution would be expected to do. The Mission Plan can then serve as a yardstick by which Congress—and a board of directors or any other body, including the public—can oversee the activities and expenditures of the waste management agency and measure its progress.

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[12] The questions involved in establishing an independent agency are discussed in ch. 7.

Relationship to Defense Waste Programs.—The separate program office established by NWPA focusses on civilian radioactive waste management. Programs for dealing with wastes generated by DOE defense-related activities are managed under the Assistant Secretary for Defense Programs. However, NWPA also requires that the Secretary of Energy make arrangements to use the repositories developed pursuant to the Act for disposal of defense high-level waste unless the President determines, after a study required by the Act, that separate repositories for such wastes are needed. The draft report from that study, released in 1984, concludes that placing the defense waste in the commercial waste repositories will be the most cost-effective option.[13] Such an arrangement could also reduce concerns that separation of the civilian and defense waste disposal programs could lead to indefinite deferral of progress on disposal of defense waste. However, if the civilian waste management program must accept defense waste as well, provisions may be required to ensure that the agency's ability to keep to the schedule for repositories—and thus to fulfill the commitments made in the contracts with nuclear utilities—does not depend on the Federal appropriations needed to fund the defense side of the program. Specifically, the Mission Plan must show how the defense and commercial disposal activities will be integrated.

Element III:

Credible measures for addressing the specific concerns of the States and the various publics.

Because of the legacy of distrust, explicit measures and guarantees are needed to give confidence about the integrity of decisions concerning the siting, construction, and operation of waste disposal facilities. Concerns about the safety and equity of Federal waste management activities by affected States, localities, and the general public could become a source of increasingly effective opposition to implementation of a waste management program unless specific measures are adopted to deal with these concerns. Efforts to proceed without dealing with these concerns may simply provoke greater resistance, confrontations, and failures to achieve program objectives on schedule. Recognition of these concerns in the waste management program is likely to broaden support for it in the first place, reduce opposition during implementation, and remove grounds for complaint.

A: **Development of explicit plans and provision of assured funds for involvement of the lay and technical publics.**

Public Involvement.—An effective program of public involvement and information may be essential for developing the broad public support needed for a waste policy to succeed.[14] On this point, NWPA recognizes that "public participation in the planning and development of repositories is essential in order to promote public confidence in the safety of disposal." Public involvement may be particularly important in the creation of an independent agency with independent funding, which could be regarded as less responsive to public concerns than the existing institutional structure. Although considerable opportunity for public involvement in Federal activities is already required by existing law and administrative procedure, NWPA provides a number of specific opportunities for public input to siting considerations, such as public hearings in the vicinity of potential repository sites, before key decisions are made. However, public confidence that an adequate and sustained level of resources will be devoted to public involvement during the development and implementation of a waste management program could be increased if DOE included a comprehensive plan for public involvement as part of the Mission Plan.

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[13] U.S. Department of Energy, *An Evaluation of Commercial Repository Capacity for the Disposal of Defense High-Level Waste*, DOE/DP-0020 (DRAFT), July 1984.

[14] Public involvement is discussed further in ch. 8.

Peer Review.—Because confidence that a geologic repository will perform as desired over a period of millenia must ultimately rest on confidence in the soundness of the underlying scientific analysis, extensive peer review of this analysis at each step can play an important role in assuring the public that waste will be disposed of safely. While the responsible Federal agencies generally recognize the importance of peer review, public confidence that it would, in fact, take place could be enhanced by including a peer review plan in the Mission Plan.

B: **Development of a regulatory process that makes ample allowance for the first-of-a-kind nature of the problem of demonstrating that a disposal system will provide the desired degree of isolation for millenia.**

Many believe that, with a first-of-a-kind problem such as radioactive waste isolation in general, and the first geologic repository in particular, an effective regulatory process is perhaps the most vital element for assuring the ultimate safety of waste disposal.

Developing the "Technology of Prediction."—What must be demonstrated to show that waste can and will be safely disposed of is not just the physical technology of disposal, but the institutional capability of the Federal Government to make a regulatory decision that a repository at a specific site can be expected to provide the required degree of waste isolation for a required period of time (10,000 years in tentative criteria under consideration by the Environmental Protection Agency). In addition to the physical technology, therefore, a broader "technology of prediction" is needed to show in a formal licensing process that a proposed repository is likely to meet established standards.

Since the ability of a geologic repository to isolate radioactive waste for millenia cannot be directly demonstrated, there must be heavy reliance on predictions of repository performance that are based on the use of mathematical models embodying scientific understanding of the behavior of the repository and its environment. Since such long-term prediction has never been done in a formal regulatory process, problems can be expected to arise the first time it is attempted. In addition, many analytic procedures to be used in the licensing process remain to be developed, including data collection and validation techniques, methods for verifying and validating scientific models, and the formal procedures for using such models to predict repository performance. Inclusion in the Mission Plan of a clear plan for the actions to be taken by both DOE and NRC for resolving these uncertainties about procedures before the first formal licensing proceeding begins could avoid unnecessary delays at that critical stage of the waste disposal program.

Integrity of the Repository Licensing Process.—For many who question the credibility of the Federal waste management program, confidence in the safety of waste disposal will depend on their confidence in the NRC repository licensing process. Several measures that would be included in a Mission Plan, in order to give it a high probability of success, would also increase confidence in the integrity of the licensing process. First, use of a conservative schedule for full-scale repository operation, one that can be met even if the first site submitted for licensing is rejected by NRC, should reduce concerns that pressures to meet the schedule could unduly influence the first licensing decision. Second, planning to achieve initial repository operation with a small amount of waste packaged during the R&D program, before packaging facilities are built at the repository site, could allow the 1998 deadline to be met even if NRC requires more than the minimum time allotted by NWPA for its decision on a construction authorization. This would further reduce the pressure on the licensing process. Finally, a high-confidence Plan would carry more sites than the minimum required by NWPA through two crucial steps in the siting process—site characterization and NRC construction authorization—to ensure that enough good sites would be available at the end of each stage to proceed to the next without major delay. This should reduce the concerns that a marginal site might be approved because of lack of any timely alternative. These measures are discussed in detail in chapter 6.

***C:* Provision in law of measures dealing with State and local concerns.**

A broadly supported policy will require assurances that State and local concerns about safety and equity will be addressed, and written into law, to be credible.[15] The stronger the guarantees in law, the more willing the States are likely to be to cooperate with the Federal Government. Some argue that State opposition is so strong that only Federal preemption can overcome it. It can also be argued, however, that any eventual attempt to deal with State restrictions will be more likely to succeed if strong efforts have been made to meet States' legitimate concerns.

NWPA includes two particularly important types of provisions addressing State and local concerns. First, it requires DOE to engage in an extensive process of consultation with States and affected Indian tribes throughout the site selection and development process. It also gives the State or tribe the right to veto the President's selection of a repository site, a veto that can only be overridden by joint action of both Houses of Congress. Similar provisions apply tc other waste management facilities addressed by the Act.

Second, NWPA requires DOE to make payments to States, affected Indian tribes, and in some cases local governments to compensate for the socioeconomic impacts of development and operation of waste management facilities. Confidence that these payments will be forthcoming more than a decade from now is enhanced by the stipulation that the necessary funds be provided from the Nuclear Waste Fund, rather than from appropriations from general revenues.

Some elements of a high-confidence Mission Plan would also address some of the substantive concerns of the States about the waste management program. For example, State concerns that the first repository may end up being the only one would be addressed by a requirement that a second licensed repository begin operation within a relatively short fixed period after the first. An explicit backup siting plan would also help reduce concerns that a lack of alternatives could compromise the fairness and integrity of the site selection process, as noted earlier.

CONCLUSION

NWPA contains most, but not all, of the policy elements OTA identified as being central to a broadly supported waste management policy. The Act resolved the major issues that had dominated the radioactive waste debate during several Congresses by committing to a schedule for developing geologic repositories, giving utilities the primary responsibility for interim storage until a repository is available, and clearly defining the role and powers of States and affected Indian tribes in siting waste facilities. In addition, it contains several key provisions that OTA had identified as being of particular importance to implementation of a repository program: financing through a mandatory fee on nuclear-generated electricity; and provisions for financial compensation to States and affected Indian tribes that host waste management facilities. *In OTA's view, the provisions of NWPA contain sufficient authority for a feasible waste management program based on geologic repositories.*

Certain major questions were left to be addressed later, either in the Mission Plan or in subsequent legislation dealing with the institutional arrangements for managing the radioactive waste program. The principal questions to be addressed in the Mission Plan concern the plan and schedule for repository development and operation, the scope of the implementation program (especially the siting program) for meeting that schedule, and the role of MRS facilities in the waste management program. As noted earlier, OTA's analysis suggests that a broadly supported policy would include a commitment to a conservative repository operation schedule that can be met despite the remaining technical and institutional uncertainties, backed up by an implementation program that places greatest emphasis on increasing the confidence that the schedule can be met without compromising safety, rather than on holding down the expected front-end program costs. While NWPA does not require this approach, it provides sufficient authority for its use in the Mission Plan, and provides a source of funding that can be adjusted if needed to cover the costs of a conservative program.

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[15] State and local issues are discussed in ch. 8.

Other important elements not addressed in NWPA all relate to the concept of an independent waste management agency with more funding and management flexibility than is usual with a typical Federal program. These elements are: 1) establishment of such an agency; 2) funding through multiyear appropriations from the Nuclear Waste Fund; and 3) a procedure for congressional approval of the Mission Plan as the principal mechanism for balancing the need for adequate congressional control of the agency with the need for increased flexibility of operation. As noted earlier, the history of the Federal waste management program suggests that these changes could substantially increase the likelihood that a Federal commitment to a schedule for repository operation can be kept. These changes are discussed in more detail in chapter 7.

At the time NWPA was being debated, alternatives to the existing institutional structure for waste management had been studied less thoroughly than the technical options. It was felt to be unnecessary and premature to attempt to make major changes before a long-term technical program had been adopted. Instead, Congress chose to correct some of the most obvious institutional problems by establishing the Office of Civilian Radioactive Waste Management within DOE. Congress chose to leave the question of more basic structural changes for consideration following submission by DOE of a study of alternative institutional arrangements for managing the waste program.

OTA's analysis indicates that development by DOE of a Mission Plan that is widely viewed as achievable and as responsive to the principal concerns of the major affected parties is the crucial next step, both for stabilizing the waste management program, and for establishing the level of confidence that would be needed before a more flexible and independent waste management organization could be established. If the Mission Plan leaves some affected parties strongly dissatisfied with the way that the major questions left open by NWPA are resolved, the risk of future policy shifts such as those that have characterized the program in the past will continue, and the credibility of long-term commitments will suffer. In addition, it is likely that such dissatisfaction would lead to strong opposition to giving the waste management program any greater managerial and financial independence than it already has. The following chapter presents the basic elements of a Mission Plan that is consistent with the authority provided by NWPA and that will be, in OTA's opinion, feasible and responsive to the principal concerns of the major affected parties.

Chapter 6

The Mission Plan

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Chapter 6

The Mission Plan

INTRODUCTION

With the enactment of the Nuclear Waste Policy Act of 1982 (NWPA), the Federal Government has, for the first time, committed itself in law to a specific date—January 31, 1998—for beginning the disposal of nuclear waste in a geologic repository. Meeting that commitment will require the Government to surmount many unprecedented technical and institutional challenges in a sustained effort over a period of decades. If that commitment is to be credible—particularly in view of past problems—it must be supported by a Mission Plan that makes ample allowance for the technical and institutional uncertainties associated with development of the first geologic repository.

In developing the Mission Plan, two points must be considered. First, *it is important to develop a Plan that will be widely regarded as feasible and achievable, to show that there is at least one workable approach to managing spent fuel and high-level waste using the authority provided by NWPA.* OTA believes that this can be done relatively quickly by using a conservative system design based on currently available information and analysis. While such a Plan would not be optimal, the credibility of the Federal waste management program is far more dependent on the realism and achievability of the Mission Plan than on its optimality.

Second, it may be possible to reduce significantly the radiation exposure to workers and the public, the costs, and the overall complexity of the waste management process by developing a carefully integrated waste management system design. However, the analytical basis needed to design an optimized integrated system is still under development. Further research, development, and demonstration (RD&D) on waste container designs for such a system will also be required.

For these reasons, the Mission Plan would contain two elements: 1) an achievable initial Plan that includes ample allowances for those uncertainties, and 2) a strategy for revising the initial Plan as appropriate in the light of new data and experience. Each is discussed below.

AN ACHIEVABLE INITIAL PLAN

Basic Elements of the Initial Plan

As part of its analysis, OTA developed an initial Mission Plan that is: 1) consistent with the authority provided by NWPA, 2) likely to be achievable, and 3) responsive to the principal concerns of the major affected parties. While it is sometimes referred to hereafter as the "OTA Plan," this approach represents for the most part an expansion, rather than a major redirection, of the approach that the Department of Energy (DOE) has followed in the past and presented in the *Draft Mission Plan* released in the spring of 1984. The following sections summarize the basic elements of the OTA Plan and compare it with DOE's *Draft Mission Plan* in order to highlight key issues.

OTA's proposed Mission Plan emphasizes certainty and places great weight on the importance of minimizing the risk of major programmatic delays or failures. Because of the long history of difficulties in the Federal waste management program, there is limited tolerance for failures. Any major failure—real or perceived—could have grave consequences for both the waste management program and the future use of nuclear power. Thus, the Plan described below is designed to give a high level of confidence that it both *can* and *will* be achieved.

To ensure it can be achieved, the OTA Plan includes a *conservative waste management plan* that can be met despite remaining uncertainties. Because geologic repositories are the only large-scale waste facilities authorized and required by NWPA, the heart of a waste management plan based on the authority provided by NWPA is a *repository loading schedule:* a target schedule for moving spent fuel from reactor sites (where practically all of it will be stored) to Federal geologic repositories.

The crucial decision concerning the repository loading schedule is the balance between the degree of *certainty* that the schedule can be met, and the *promised speed* of the schedule. Developing a geologic repository is a complex endeavor involving many first-of-a-kind technical and institutional steps. The faster the promised schedule, the less margin there is for delays or problems at any of these steps, and the less confident one can be that the schedule can be met. To provide utilities and the communities near reactors with a highly reliable schedule for removing spent fuel from interim storage, the OTA Plan emphasizes certainty by using a repository loading schedule that does not require everything to go smoothly the first time.

The OTA Plan also includes an *implementation program* designed to give confidence that the conservative loading schedule will be met. The crucial choice to be made in the implementation program concerns the balance between the *certainty* that the program will achieve the objectives of the waste management plan on schedule, and the *initial costs* of the program, both financial and political. *The basic fact that must be faced is that it is impossible both to maximize the certainty of achieving the objectives on schedule and to minimize the initial costs at the same time.* In designing an implementation program, DOE has essentially two choices: 1) a *preventive approach* that identifies in advance the most serious potential sources of failure and delay, and includes measures to reduce the chance that they will occur or cope with them if they do; or 2) a *reactive approach* that meets the minimum requirements and standards of the Act and assumes that no major failures will occur, or that problems can be dealt with adequately after they occur. The first approach treats the requirements of the Act as a floor rather than a ceiling on DOE's efforts. It will cost more at the start, but over the long run its financial and political costs may be less—perhaps far less—than those incurred by the other approach. Because it includes measures to anticipate and avoid potential delays and failures, the preventive approach is also likely to reduce the time required to develop an operating repository. With this approach, confidence that the Mission Plan will be carried out successfully is based on the anticipation and allowance for potential problems.

To minimize the chance of real or perceived program failures, the OTA Plan uses a preventive implementation strategy. Its central feature is the pursuit of enough backup components of the isolation system (e.g., the waste form and waste container) and candidate repository sites to ensure a high probability that at least one acceptable combination will be available on the target date, even if somewhat predictable failures occur. Such use of backups is a standard technique for achieving high reliability in technical systems.

Major Advantages of the Initial Plan

Because the Mission Plan outlined below requires DOE to go beyond the minimum requirements of NWPA, it may involve higher financial and political costs than those contemplated in DOE's *Draft Mission Plan*. These potential costs could be regarded as unnecessary by those who believe that geologic disposal is a relatively straightforward technical enterprise. However, they could also be seen as the price of insurance for a program that cannot afford any major failures or delays. If those who believe that geologic disposal will be easy to implement are proved right, this approach will produce a broad range of technical options and qualified sites *before* they are required by the conservative waste management plan. If they are wrong, this approach will be more successful at preventing major delays and will be cheaper in the long run.

While NWPA does not require this approach, it provides sufficient authority for its use and provides a source of funding that can be adjusted to cover the costs of such a program.

The Mission Plan presented below offers several other advantages. First, it can serve as an important early step toward demonstration that high-level radioactive waste can and will be disposed of safely. A Plan with adequate provisions for dealing with the remaining technical and institutional uncertainties can increase the consensus in the technical community that the waste management plan and the implementation program are feasible and that regulatory standards will be met. Second, by ensuring that cost estimates, necessary for any future revisions of the waste disposal fee, are based on a program that is widely regarded as being achievable, the Plan should significantly reduce the uncertainty about the ultimate cost of disposal that now faces utilities and ratepayers. Third, the high-confidence approach can contribute to the acceptability of the Plan, since the measures needed to give confidence that the waste management plan can be met should also address some of the key concerns of interested parties such as States and environmental groups. In particular, basing contracts on a conservative repository loading schedule that makes allowances for delays can reduce concerns that safety might be sacrificed for speed, while development of backup repository sites and technologies can reduce concerns that less-than-satisfactory options might be used for lack of any suitable alternatives.

THE WASTE MANAGEMENT PLAN

While NWPA sets a target date of 1998 for initial operation of the first geologic repository, it does not clearly indicate either how fast DOE is to accept waste for disposal after the repository is available or what is to occur if the repository does not begin operating in 1998. To fill in those crucial details, the initial Mission Plan must contain an explicit waste management plan that includes: 1) a credible repository loading schedule that could be met even if there were delays in the repository program, 2) a plan for interim spent fuel storage after 1998 (who is responsible and where storage is to be provided) if the repository is delayed, and 3) a backup plan for monitored retrievable storage (MRS) or alternative disposal facilities that would allow the Federal Government to accept spent fuel or reprocessed waste eventually, even if there are major unforeseen difficulties with geologic disposal.

Repository Loading Schedule

NWPA clearly established the Federal responsibility for disposal of high-level waste and spent fuel and adopted a schedule for development of geologic repositories for that purpose. Since the Act defines a repository as a "system . . . for permanent deep geologic disposal," and disposal as "emplacement in a repository," the geologic repositories required by the Act are the only facilities that DOE can use to discharge the Federal responsibility for high-level waste disposal. *Thus, a conservative initial Mission Plan based on the authority now provided by NWPA would focus on the credibility of the repository loading schedule as the basis of the credibility of the Federal commitment to take possession of spent fuel and ultimately remove it from reactor sites.*

The schedule for the first geologic repository is of particular importance, because that repository is the only large-scale waste management facility that NWPA authorizes DOE to construct. Although DOE is required to find a suitable site for the second repository and submit it to the Nuclear Regulatory Commission (NRC) for licensing, further authorization by Congress will be needed for construction of that repository. (As discussed below, the Act's limitation on the amount of spent fuel that can be placed in the first respository before the second begins operation will require eventual construction of the second to accommodate the spent fuel expected to be generated by the reactors now operating or under construction.) NWPA also directs DOE to prepare site-specific designs for MRS facilities, but the Act neither authorizes nor requires DOE to actually site or construct such a facility.

The rate at which spent fuel can be transferred to repositories will be determined primarily by the dates on which the facilities begin operation and by the loading rate of each repository. These are discussed below.

Schedule for Full-Scale Operation of the First Repository

A major reason for the contractual commitment to a schedule for accepting waste at a repository, included in the integrated waste management policy described in chapter 5, is to provide a basis for confidence that spent fuel will ultimately be removed from reactor sites to a permanent resting place, and thus that interim storage will not become a long-term measure by default. OTA's study concluded that *the single most effective measure to facilitate efforts to provide additional interim spent fuel storage is to provide a highly credible schedule and program for siting and operating geologic repositories.*

To create confidence that interim storage would indeed be interim and not permanent, the certainty of the schedule for repository operation is more important than the speed. Thus the Mission Plan would contain a conservative repository loading schedule that is a *high-confidence prediction of when repositories are likely to be operating despite the kinds of delays that might be anticipated in a first-of-a-kind venture.* Such a repository loading schedule must take into account four broad sources of uncertainty: 1) the time that will be required for the technical and institutional steps involved in characterizing and licensing the first repository site, 2) the possibility that NRC will not grant a construction authorization or operating license for the first site submitted for approval, 3) the possibility that the disposal system design might be rejected by NRC or might require substantial modifications to meet regulatory requirements, and 4) the possibility that the target loading rate of each repository cannot be achieved in practice. A repository loading schedule that would provide for these uncertainties would allow ample time for: 1) delays in the siting and licensing process, including rejection of the first site submitted to NRC and the licensing of a backup; and 2) development, licensing, and demonstration of two disposal system designs at the first repository site, before the full-scale packaging and loading facilities are constructed.

The Plan will also need to include more optimistic management goals that show the earliest time that spent fuel could be delivered to the Federal Government, if all goes well. Such goals are needed as program management tools to prevent the allowances for delay in the conservative loading schedule from being used up by avoidable procrastination. *However, to avoid raising false expectations, such management goals should be clearly distinguished from the conservative "best estimate" schedule used as a basis for contractual commitments.* Questions about the credibility of the Federal waste management program in the past have stemmed in part from plans and schedules that could only be met if no technical or institutional difficulties arose. The credibility of the Mission Plan would be enhanced if contractual commitments are based on a conservative repository loading schedule that does not assume that everything will go right the first time.

MANAGEMENT TARGET SCHEDULE

The repository management target schedule suggested here provides for operation of the first repository to be accomplished in two phases—*a demonstration phase* and an *operational phase*. These phases are designed to address separately the two distinct reasons for a repository:

1. *To demonstrate that a suitable disposal technology exists and that NRC will license it.* This is needed to allay concerns that there is no solution to the waste disposal problem and can be accomplished with initial licensed emplacement of waste in a repository.
2. *To dispose of radioactive waste at a scale comparable to the rate at which it is being generated.* This is needed to ensure that at some definite point waste will actually be removed from storage and moved to a permanent resting place. It requires a full-scale operating repository system.

The target for initial operation in the demonstration phase is January 31, 1998, as required by NWPA. For this phase, a small amount of waste (e.g., several hundred tonnes) would be placed in conservatively designed packages during the generic packaging and handling RD&D program required by NWPA. Permission would be requested from NRC to emplace this material in the repository as soon as possible following issuance of a construction authorization, before the repository's packaging facilities are constructed.

Providing for separate demonstration and operational phases of operation of the first repository offers several advantages:

1. *It increases the likelihood that the 1998 deadline for initial repository operation will be met.* Analysis by DOE indicates that the 1998 deadline probably cannot be met if operation of the first repository is deferred until the full-scale packaging and handling facilities can be built.[1] Under the conservative Plan described in this chapter, initial emplacement of waste in the repository would be accomplished before the repository's packaging facilities had been constructed. This should minimize the time between the construction authorization and the first licensed disposal in the repository, thus increasing the chances that the 1998 deadline can be met even if there are delays in receiving the first construction authorization.
2. *It allows an early demonstration of licensed disposal.* What is needed to demonstrate that radioactive waste can and will be safely disposed of is not only the physical technology of disposal, but also the institutional capacity of NRC to make a regulatory decision that a repository at a specific site can be expected to provide the required degree of waste isolation. NRC approval of a licensed phase of low-level operation, as soon as possible after the construction authorization is granted, could provide an early demonstration of both the physical and institutional requirements for disposal. Licensed low-level operation may also be adequate to satisfy the requirement in some State moratorium legislation that no new nuclear reactors be licensed until a demonstrated disposal technology has been approved by the Federal Government.[2]
3. *It allows time to optimize the system design for the operational phase.* Meeting the January 1998 deadline with an initial phase of low-level operation could also separate the question of demonstrating the existence of a disposal technology from that of full-scale operation. The demonstration phase would use a conservative repository system design (discussed below), based on the principle that the certainty of obtaining NRC approval with a minimum of technical disputes should take priority over cost-effectiveness. Deferring the operational phase would allow more time for DOE to develop, and NRC to approve, a full-scale system design in which broader waste management system considerations such as cost and worker radiation exposures are given higher priority. This might allow relaxation of initial conservatisms in repository design, if justified by the results of low-level operation and testing, thus reducing the risk that adoption of a conservative baseline system design in the initial Mission Plan could lead to costs that later prove to be unnecessary.

This approach may also reduce disposal costs in the long run compared to DOE's proposed approach, which involves construction of full-scale packaging and handling facilities quickly after a construction authorization is granted.[3] There are several sources of possible cost savings. First, this approach allows time to develop and license an optimized system design. As noted earlier, recent studies suggest that it may be possible to significantly reduce total waste management system costs and radiation exposures during operation by using a carefully integrated system design.[4] DOE's current plans may not allow time to develop and incorporate an optimized integrated design in the first repository, however, since DOE did not formally initiate an effort to develop concepts for an integrated system until 1984. To avoid foreclosing prematurely the option of using such an integrated system for the first repository, *the DOE management target schedule for construction of the full-scale packaging and handling facilities for the operational phase would be determined by the time required to develop, test, and license an optimized integrated system design.* Whether or not this would require an adjustment of several years in DOE's current planning schedule (for operation of full-scale facilities in 2001) is by no means certain. However, the potential benefits to be obtained could more than offset the cost of the additional storage required if a delay of several years were involved.

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[1] U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 1984, pp. 3-A-36 and 3-A-37 (hereafter *Draft Mission Plan*).

[2] Analysis by the presiding member of the Nuclear Fuel Cycle Committee of the California Energy Resources Conservation and Development Commission concludes that the last step needed for demonstration is confirmation of the existence of a suitable site. Emilio E. Varanini, III, "Aspects of Demonstrating Nuclear Waste Disposal," statement presented to the Waste Disposal Technology Symposium, University of Arizona, Tucson, Ariz., Feb. 27, 1979. This could be accomplished by NRC approval of initial disposal at a site.

[3] DOE's *Draft Mission Plan* includes two phases of repository operation but initiates construction of the full-scale facilities at the same time as the pilot-scale facilities. There is no allowance for a period of low-level operation before the design of the full-scale facilities is locked in. Instead, the two-phase aproach is used primarily as a way of meeting the 1998 deadline, rather than allowing time to develop and test an optimized system design before commiting to construction of the full-scale system.

[4] Raymond E. Hoskins, "Concept for an All-Purpose Transport, Storage and Disposal Cask for Spent Nuclear Fuel Management," published in *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting,* CONF-831217, U.S. Department of Energy, February 1984, pp. 362-368. See also Westinghouse Electric Corporation, Waste Technology Services Division, *Preliminary Cost Analysis of a Universal Package Concept in the Spent Fuel Management System,* WTSD-TME-432, September 1984.

Second, it would provide greater certainty that the full-scale system could be operated at the target rate required by the repository loading schedule, since the final design would have the benefit of the experience gained during low-level operation in the demonstration phase. This would reduce the risk of costly and time-consuming modifications to an already constructed facility unable to operate at the target rate.[5]

Third, it would allow more time to resolve questions about whether and when spent fuel might be reprocessed. This would allow the operational disposal system design to be optimized based on better information about the relative proportions of spent fuel and high-level waste from reprocessing it would have to handle, and would reduce concerns that irreversible decisions about the fate of spent fuel would be made prematurely.

Fourth, deferring the large costs of full-scale operation can reduce the total discounted cost of disposal, thus offsetting to some extent the costs of the additional interim storage that would be required.

CONTRACTUAL REPOSITORY LOADING SCHEDULE

The repository loading schedule used for contracts with utilities would be based on operation of full-scale loading facilities beginning no later than 2008 at the first repository. This date is a credible basis for commitments because, unlike the more optimistic management schedule, it can be met even if significant technical and institutional difficulties are encountered. For example, the first repository could be operating by 2008 even if none of the sites initially evaluated at depth ("characterized") proved acceptable and a new site not now under consideration had to be used. (By contrast, the DOE *Draft Mission Plan* estimates that the *second* repository could be operating by 2004, even if both a new site and a new geologic medium [granite] were used.) Spent fuel could be accepted some years earlier than the commitment date if the contingencies that have been allowed for, such as the need to use a backup site, do not materialize—provided that the repository program has been managed firmly enough to prevent the allowances from being used up by avoidable delays.

The 2008 commitment date for operation of full-scale facilities at the first repository is consistent with some independent assessments of the likely availability of a repository. NRC has determined in its "waste confidence" rulemaking that there is reasonable assurance that a geologic repository would be available between 2007 and 2009.[6] The Tennessee Valley Authority, in an analysis of its own needs for additional spent fuel storage, estimates no better than a 50-50 chance that DOE will be able to accept spent fuel on a large scale by 2008.[7] OTA believes that use of the implementation program described below can substantially increase the level of confidence that a repository would be available by that time.

Schedule for Operations of the Second Repository

The Act does not commit to a specific date by which the second repository is to come on line, but rather sets a limit of 70,000 tonnes on the amount of spent fuel or equivalent high-level waste that can be placed into the first repository before the second begins operation. DOE analysis shows that the second repository could open by 2005, at the earliest, if the first site recommended for that repository is approved by NRC and there are no substantial delays in the siting process. At most, it could open as late as 30 years after the first, since it would take about that long to emplace 70,000 tonnes in the first repository, according to DOE's most recent repository loading schedule. (It should be noted that because the reactors that are currently operating or under construction are expected to discharge over 100,000 tonnes of spent fuel during their lifetimes, the 70,000-tonne limit on the first repository implies that the second *must* ultimately be built if projected amounts of waste are to be accommodated without amendment of NWPA.)

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[5] While the DOE *Draft Mission Plan* provides for an initial phase of repository loading using partial loading facilities, it does not allow time to test the loading facility design before full-scale facilities are constructed. Since there is no experience at packaging and handling highly radioactive materials at the rates expected during full-scale repository operation, constructing the full-scale facilities without experience at an intermediate scale increases the risk that repositories will not be able to achieve their target loading rates in practice.

[6] *Federal Register*, vol. 48, No. 99, May 20, 1983, p. 22730.

[7] Hoskins, op. cit.

The proposed Mission Plan would commit to operation of the full-scale facilities of the second repository to begin no later than 2012—4 years after the commitment date for full-scale facilities of the first repository. An explicit commitment to operation of a second repository soon after the first would allay concerns that the first repository would become the Nation's sole "nuclear waste dump" for many decades, and would provide a backup to the first repository to ensure that some disposal operations could take place even if problems developed with one repository. In addition, if an acceptable site for a second repository can be found nearer the bulk of the reactors in the East, it will significantly reduce the costs and impacts of full-scale transportation of high-level radioactive waste from reactors to disposal. Planning for a short delay between operation of the first and second repositories allows more time to identify suitable sites in the East, and time for experience at operating the first repository before the second starts up.

Target Full-Scale Annual Loading Rate

The target loading rate of each repository is a major design decision affecting the entire waste management system. It will determine how long each repository will be in operation, how quickly the buildup of spent fuel in storage at reactors can be stopped, and how long it will take to eliminate the backlogs that are already in storage at the time repository loading begins. The higher the target loading rate, the more rapidly the backlogs can be eliminated. At the same time, increasing the repository loading rate will increase the cost of the packaging and handling facilities, the number of transportation casks needed to deliver waste to the repository, and the number of shipments needed each year.

Three considerations are relevant to choosing a design maximum loading rate: the projected types and amounts of waste that must be accepted, the goal for removing waste from interim storage, and the desired reserve margin in the loading capacity. Each will be discussed briefly.

WASTE PROJECTIONS

A waste management plan must be based on some assumptions about the amount of spent fuel that will be generated in the future. The more reactors that are expected to be operating when the repositories begin operation, the greater the loading capacity that will be needed to stop the buildup of spent fuel in storage. OTA suggests that, as a base case for the waste management plan, DOE consider the spent fuel expected to be generated by the reactors that are now operating or are under construction (see fig. 6-1). If additional reactors are ordered in the future, the Mission Plan can be revised as needed. (If the increase over currently planned construction is relatively small, it could probably be handled by increasing the design loading rate of one or both of the two repositories required by the Act, or by extending the operational period of the repositories. If the increase is large, additional repositories may be required.) This would provide a conservative basis for estimating the fee that will have to be charged to ensure full-cost recovery, as required by NWPA. A fee based on the expectation of revenues from reactors that have yet to be ordered could turn out to have been too low if those orders do not materialize,[8] and could produce insufficient revenues in the early years of the program.

The waste projections must also make assumptions about the relative amounts of spent fuel and high-level waste from reprocessing that would be delivered for disposal. A conservative assumption is that all spent fuel would be delivered directly to

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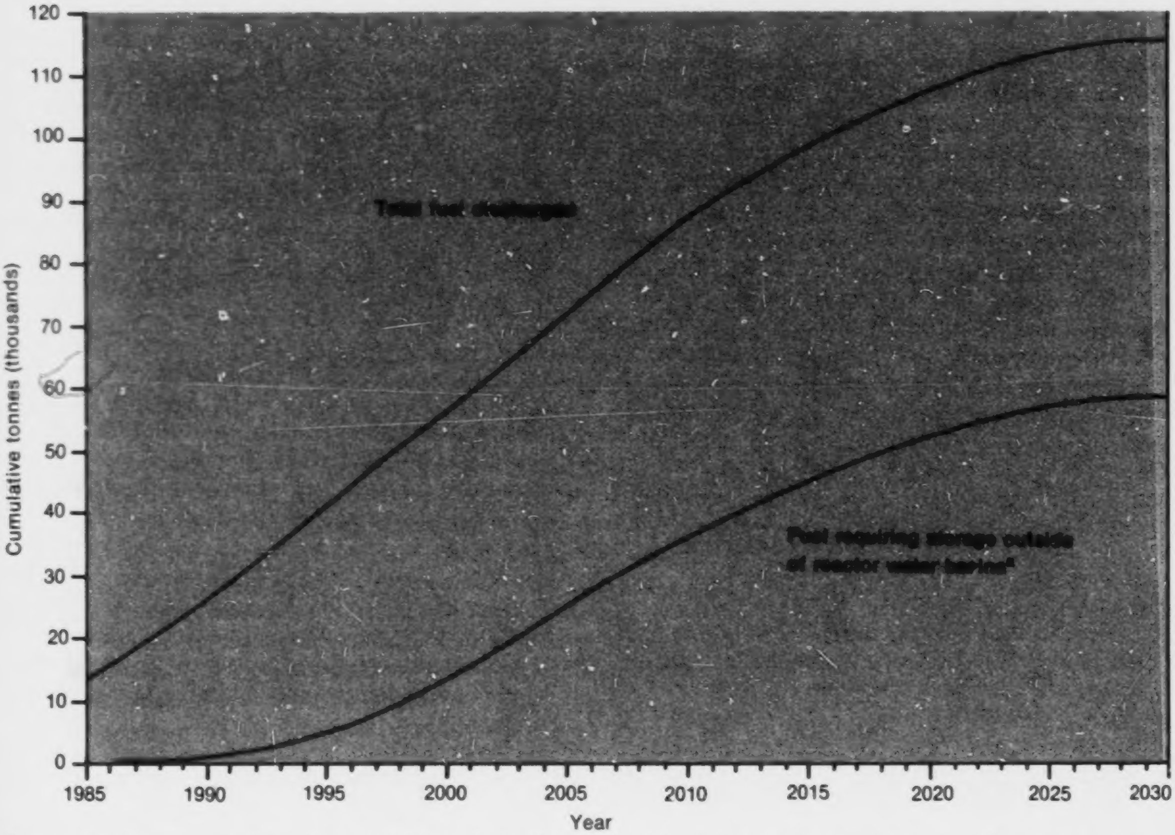
[8] U.S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020 (Washington, D.C., June 1983), p. 30.

Figure 6-1.—Spent Fuel Projections: LWRs Operating and With Construction Permits on Dec. 31, 1982



[a]Assumes basins are reracked to the maximum extent, but no rod consolidation. Consolidation could significantly increase the capacity of the existing basins.

SOURCE: Data supplied by U.S. Department of Energy (see app. E).

repositories without reprocessing. This would give a high estimate of the number of packages of highly radioactive waste to be received, packaged, and emplaced in each repository each year, since it is expected that there would be fewer packages of solidified high-level waste than of spent fuel for a given amount of electricity generation. At the same time, a conservative plan would provide capacity to dispose of the high-level waste from the West Valley reprocessing plant and the defense nuclear programs.

Planning to provide capacity for direct disposal of all spent fuel simply ensures that disposal will be available as an option according to the planned schedule, not that spent fuel must be disposed of according to the schedule. Thus, it does not preclude future decisions to defer disposal. In fact, once the repository packaging and handling facilities needed to meet the reference loading schedule have been constructed, it would be possible to store the packaged spent fuel on the surface at the repository if that were desired.

GOAL FOR REMOVING WASTE FROM STORAGE

DOE estimates that by 1998, some 36,000 tonnes of spent fuel will be in storage (practically all of it at reactor sites), and about 2,300 additional tonnes will be discharged each year by the reactors that are in operation at that time.[9] While it is possible that one repository loading at 3,000 tonnes per year could handle the total annual discharge from the reactors that are already operating or under construction, it would have little capacity left over to begin reducing the backlog. A major design question, then, is how much loading capacity to provide beyond the amount needed to stop the buildup of spent fuel. This decision will depend upon how quickly it is desired to remove waste from interim storage sites, and, in particular, how quickly to remove spent fuel from reactor sites.

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[9] U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, September 1984, table 1.2, p. 30.

As discussed in chapter 3, once fuel has been placed into storage, it may be cheaper to leave it there for an extended period than to construct the additional transportation and disposal capacity needed to allow it to be removed quickly. Furthermore, NRC has concluded in its "waste confidence" rule that spent fuel can be left safely at reactor sites up to 30 years after expiration of the reactor's operating license. Nonetheless, the prospect of spent fuel remaining in storage at reactor sites for decades after the reactors cease operation may be objected to by the surrounding communities and may be viewed as a negative factor in decisions about siting and construction of new reactors. The repository loading schedule must strike a balance between these considerations.

Allowing 10 to 15 years after reactor shutdown for spent fuel removal could be advantageous because it would avoid the strains on the transportation and handling systems that would result if a reactor's lifetime discharge had to be removed within a few years.[10] In addition, designing and licensing the transportation cask fleet to handle only fuel that is at least 10 years old would provide an additional safety margin because of the reduction in heat output of the fuel.[11] Under the current DOE contract, spent fuel must be at least 5 years old before it can be delivered to DOE, which means that some spent fuel will remain at reactor sites for at least 5 years after decommissioning.

Operation of full-scale facilities of the first repository as late as 2008 and the second repository as late as 2012 would not lead to large amounts of spent fuel being left at reactor sites for an extended period after decommissioning. Even with that schedule, two repositories, each loading at 3,000 tonnes per year, could dispose of all the spent fuel expected to be generated by the reactors now operating or under construction by about 2030, and could ensure that spent fuel is removed from each reactor site within 10 to 15 years after the reactor ceases operation.[12]

RESERVE MARGIN

Confidence that the desired annual loading rates will be achieved in practice can be increased by planning to construct one more independent processing line than the minimum expected to be required to meet target loading rates. Available studies suggest that a single processing line may be capable of achieving the loading rate of 3,000 tonnes per year now being used in DOE plans.[13] However, construction of two lines provides a reserve margin that can, in several ways, increase the confidence that that rate will be achieved in practice.

First, the loading rate depends on both the number of packages per year that the processing line can handle and the amount of waste that can be placed in each package. Even if one line is able to process the required number of packages each year, it is possible that site-specific considerations might require a lower package waste load than anticipated. Provision of a second packaging line would allow the waste load per package to be reduced by half without lowering the total loading rate.

Second, the reserve margin provided by a second packaging line is insurance against the possibility that unanticipated operational difficulties might force each line to operate at a lower rate than planned. The risk that this would occur could be reduced by planning to begin full-scale operation following construction of the first processing line, and to defer construction of the second until the design is confirmed in practice and any needed modifications are made.

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[10] Ali Ghovanlou et al., *Analysis of Nuclear Waste Disposal and Strategies for Facility Deployment,* The MITRE Corporation, (McLean, Va., April 1980), p. 6-51.

[11] As discussed in ch. 3, cask design studies show that increasing the age of fuel from 5 to 10 years leads to a 100° F reduction in maximum fuel temperature during a design-basis fire.

[12] Data on light-water reactors that are operating and with construction permits provided by DOE. See app. G for calculations.

[13] Westinghouse Electric Corporation, Advanced Energy Systems Division, *Engineered Waste Package Conceptual Design Defense High Level Waste (Form 1) and Spent Fuel (Form 2) Disposal in Salt,* AESD-TMA-3131, September 1982, pp. 422-423.

Third, a second processing line provides backup loading capacity against the possibility of accidents or other problems that would halt, interrupt, or slow down the operations of the first line, or loading of the other repository. In fact, if a single line proves capable of handling the target rate of 3,000 tonnes per year, the second line would provide fully redundant capacity to handle material intended for the other repository if loading of that repository were halted for any reason.

Addition of a second processing line is estimated to cost between $18 million and $60 million, depending on the package design.[14] In addition to increasing confidence that the loading schedule will be achieved, it could also allow defense high-level waste to be loaded in the repository (if a decision is made to do so) without seriously affecting the loading of commercial waste.

Storage: The Role of the MRS in the Waste Management Plan

Although the major focus of NWPA is the siting and operation of two permanent geologic repositories, the Act also requires DOE to submit designs for, and a study of the need for, one or more monitored retrievable storage (MRS) facilities. This study is to be submitted to Congress in mid-1985, to provide a basis for possible deliberations concerning whether to authorize siting and construction of such a facility.

Proposals for construction of Federal storage facilities have played a major role in debates about waste management policy since 1974, when the Atomic Energy Commission, following failure of the attempt to site a first repository at Lyons, Kansas, suggested Retrievable Surface Storage Facilities (RSSFs) as an interim measure to allow several decades to develop permanent disposal facilities. (See the discussion of storage in ch. 4 and app. A.) Two distinct functions have been proposed for such storage facilities:

1. To provide relatively short-term interim storage as part of a waste management program predicated on fairly rapid development and operation of geologic repositories. This role was the focus of debate on the Carter administration's proposal to provide Federal away-from-reactor (AFR) storage facilities in the 1980's, discussed in issue 4 of appendix B.
2. To provide a long-term waste management option that would allow more time to be taken in developing geologic repositories or other disposal technologies (the proposed role for the RSSF), or to serve as an alternative to geologic repositories in the event that such repositories cannot be developed for a long, and perhaps indefinite, period. The construction of long-term storage facilities as an alternative to rapid development of geologic repositories is discussed in issue 1 of app. B.

Proposals for construction of MRS facilities have included both functions. It would be valuable for the Mission Plan to analyze the need for each of these principal functions in an integrated waste management system. This would provide a useful perspective for the plan, required to be included in the MRS need and feasibility study, for integrating any MRS facilities that are constructed with the other storage and disposal facilities authorized by the Act. Such analysis would also be responsive to NWPA's requirement that the Mission Plan provide "an informational basis sufficient for informed decisions." A brief discussion of each function follows.

Post-1998 Interim Storage

While the repository program is the principal focus of the Mission Plan, it must also address the issue of interim storage after the 1998 deadline for repository operation. Additional storage capacity will be required after 1998 for three reasons:

- Even if the repository begins operating on schedule in 1998, it will take some time to reach a high enough annual loading rate to equal or exceed the rate at which spent fuel is being generated. DOE currently estimates that this would not occur until 2003.[15]
- Some slippages in the repository operation schedule are possible if not likely. Even a conservative repository development program might experience some relatively short delays resulting from foreseeable but unavoidable

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[14] Ibid., pp. 423 and 434.

[15] DOE, *Draft Mission Plan*.

events such as lawsuits, construction accidents, rejection of a repository site, strikes, and bad weather. While such events could delay repository loading by years, they would not lead to extended or open-ended delays and would not raise major questions about the eventual availability of geologic repositories.

- Even after the repository is operating at full scale, there will be a need for buffer storage capacity in the waste management system to allow reactors to continue operating without disruption even if there are any operational difficulties at the repository that would prevent it from accepting spent fuel at the desired rate.

NWPA provides that utilities be responsible for additional interim storage as needed until DOE can accept the waste at a repository, and the Act does not authorize construction of Federal storage facilities. In accordance with this law, an initial Plan based on the authority in NWPA would provide for *interim storage by utilities at reactor sites until a repository or alternative long-term waste management facility is available.*

Providing post-1998 interim storage at reactor sites appears to be quite feasible.[16] NWPA contains measures to facilitate utility efforts to provide at-reactor storage until a repository is available, and, as noted earlier, NRC has concluded in its waste confidence rulemaking that spent fuel could be safely stored at reactor sites for up to 30 years after termination of the reactor license. Thus, if no further action were taken by Congress to authorize storage by the Federal Government, it appears now that the needed storage could and would be provided by the utilities themselves. This shows that the existing authority provided by NWPA is sufficient to carry out a workable waste management program unless currently unforeseen major problems are encountered in developing geologic repositories.

Nonetheless, discussions concerning the Mission Plan have raised the issue of whether the Federal Government has a responsibility or an obligation to take spent fuel after 1998 if a repository is not available as required by NWPA. This involves two interrelated questions: *who* should be responsible for post-1998 interim storage, and *where* should it be done? These need to be discussed separately, although they are often merged in the comparison of two alternatives: utility responsibility, with storage at the reactor sites; or Federal responsibility, with storage at an MRS facility. There is also a third option that bears consideration, since NWPA allows DOE to take title to spent fuel at reactor sites: Federal responsibility for post-1998 storage at the reactor sites.

RESPONSIBILITY FOR POST-1998 INTERIM STORAGE

Some feel that NWPA requires utilities to provide interim storage for as long as is necessary until a repository is available. Others feel that the Act's 1998 deadline for a repository, and the fact that utilities are now paying fees for disposal services, obligates the Federal waste program to take responsibility for spent fuel beginning in 1998. This is primarily an equity issue rather than a technical question, since NWPA allows DOE to take title to spent fuel at the reactor sites before it is delivered to a repository. Thus, title and responsiblity could be transferred according to any arbitrary schedule that could be agreed upon. The options range from continuation of utility responsibility until spent fuel is physically delivered to the repository, to having the waste management program take responsibility for all spent fuel in 1998. OTA's analysis of an integrated waste management policy concluded that it may be possible to reach agreement on the principle that the costs of additional spent fuel storage, beyond the contractual acceptance date (and perhaps title to and liability for the spent fuel), would be transferred from the utility to the waste management program on that date.

It should be noted that under NWPA, the costs of the waste management program are to be recovered from users through fees. Thus, any costs for additional interim storage would be paid for by utilities rather than the Federal Government, whether that storage is provided by the utilities directly or by the Federal waste management program. The question is whether the cost will be paid only by those utilities that would have to provide additional storage if the repository loading schedule is delayed, or by all utilities through the Nuclear Waste Fund.

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[16] DOE "expects the increased efficiency of onsite spent fuel storage, that is expected to result from successful completion of the fuel rod consolidation and dry storage demonstrations (now underway), to be sufficient to preclude the need for Federal Interim Storage." DOE, *Draft Mission Plan,* p. 3-D-5.

NWPA currently requires that utilities, to the extent possible, provide interim storage until the spent fuel is accepted by the waste management program, and requires that the costs of the limited 1,900-tonne Federal interim storage program be borne by those utilities that use it. While NWPA provides that any MRS facilities subsequently authorized by Congress would be paid for from the Nuclear Waste Fund, it also requires that the MRS proposal be accompanied by a funding plan that would provide that the costs of constructing and operating such facilities be borne by the generators and owners of the material to be stored in the facilities.

While the decision about who is responsible for post-1998 spent fuel storage would affect primarily the equity of the distribution of waste management costs among the utilities themselves, it could also affect the total costs to the utilities. This will depend on the interest rate set by the Secretary of the Treasury for borrowing by the Nuclear Waste Fund in years when the expenditures exceed the revenues from the waste disposal fee. If that rate is set at the rate for Government securities, rather than at competitive market rates that utilities would face if they were raising capital themselves, shifting the storage costs to the waste management program could reduce the total costs to the utilities and would to some extent represent an implicit Federal subsidy to the waste management program.

LOCATION OF POST-1998 INTERIM STORAGE

If the utilities are responsible for interim storage, it appears likely that most of the storage would be located at reactor sites. If the Federal waste management program takes responsibility, the storage could be done either at centralized MRS facilities located away from the reactor sites, or at the sites themselves, using one of the dry storage technologies that will be demonstrated as part of the program required by NWPA. If combination storage/transportation casks prove feasible and licensable, DOE could simply provide those casks to utilities as needed to store spent fuel that cannot be stored in the reactor basin, since DOE has authority under NWPA to provide transportation casks. (DOE has suggested this option in the *Draft Mission Plan.)* Once a repository begins operation, title to the spent fuel could also be transferred to DOE at any desired rate even if the target loading schedule is not achieved, since title can transfer at the reactor site.

If multipurpose casks are not feasible, Congress could authorize DOE to provide other storage facilities directly at reactor sites, as is already authorized under the limited Federal interim storage program in NWPA. This approach may be desirable unless there are substantial safety and cost benefits to centralized storage, and it would avoid the potential complications of siting and licensing MRS facilities.

If DOE provided additional storage using multipurpose casks, the costs would be borne by the waste management program rather than by the individual utility. If Congress authorizes DOE to construct additional storage facilities, either a centralized MRS or at-reactor facilities, a decision could be made at that time about whether the costs would be borne by all utilities.

The questions involved in providing a centralized Federal MRS for post-1998 interim storage are essentially similar to those involved in earlier proposals for a Federal AFR storage facility that were considered at the time NWPA was being debated. (These questions are discussed in issue 4 of app. B.) The major difference is that the interim storage provisions of NWPA have dealt with a principal argument made for a Federal AFR: the concern that utilities would not be able to provide additional storage capacity quickly enough to prevent reactor shutdowns. As noted earlier, it now appears likely that utilities will be able to provide their own storage by and after 1998 even if no large Federal storage facility is provided. While a systematic and detailed comparison of storage options must await completion of the MRS needs and feasibility study, available studies suggest some preliminary conclusions, which are discussed below.

Available analyses suggest that decentralized at-reactor storage could be economically competitive with centralized storage, and may even be less expensive under some conditions.[17] The principal reason is that the at-reactor approach allows the capital cost of handling facilities to be spread out over time as small increments are added on a reactor-by-reactor basis as needed. A centralized approach involves a large front-end expenditure for packaging and handling facilities that may not be fully utilized, and that to some extent would duplicate at-reactor facilities that the utilities would already have constructed to meet their pre-1998 interim storage obligations under NWPA.[18]

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[17] A recent analysis of universal container concepts shows that an optimized at-reactor approach using storage transportation casks could be as much as 20 percent less expensive than an optimized approach including centralized MRS facilities. Westinghouse, *Preliminary Cost Analysis,* table 1-3, pp. 1-10 and 1-11.

In addition, expanding at-reactor storage may be more reliable than building a centralized storage facility for assuring adequate buffer storage in the event of delays in repository siting or interruptions in repository operations. A centralized storage facility would itself be subject to many of the same sorts of "expected" delays that would affect a repository. In addition, a centralized MRS facility, like a repository, would be potentially vulnerable to operational problems that could adversely affect many reactors simultaneously unless provisions have been made for buffer storage at the reactor sites. Furthermore, the history of strong and successful opposition to past efforts to provide Federal storage facilities suggests that a policy of providing MRS facilities might be relatively difficult to sustain over an extended period. Thus, the effort to develop MRS facilities may not provide much more insurance against such delays than would the measures to increase confidence in the repository loading schedule described below.

On the other hand, it is possible that a need could be shown for offsite storage before a repository can be expected to be available. For example, some reactor sites may be limited in their physical capacity for additional storage, although further analysis is needed to determine the extent to which this would lead to a requirement for offsite storage before repositories are likely to be available. (There will be a need for some spent fuel prior to that time for packaging and handling tests, dry storage RD&D, and low-level operation of the first repository. This requirement may be sufficient to eliminate any physical need for offsite interim storage beyond the 1,900 tonnes of backup offsite storage already provided for by NWPA.) It is also possible that there may be overall system benefits, in terms of safety and cost, to providing centralized facilities for the additional interim storage that would be required if all the contingencies provided for in the conservative repository loading plan came to pass. However, this remains to be demonstrated.

To provide Congress with a complete basis for its decision, it would be valuable for the MRS need and feasibility study to include an analysis of an optimum Federal at-reactor storage option for comparison with the centralized MRS options. Comparisons would be made in terms of total waste management system costs, worker and public radiation exposures, geographic distribution of waste management impacts, and vulnerability to delays or disruption of operation of any facilities in the system. Consideration of providing Nuclear Waste Fund-financed interim storage at reactor sites, as an alternative to centralized MRS facilities, would allow a comparison of the relative merits of at-reactor and away-from-reactor storage that is not complicated by institutional differences in funding and ownership arrangements between the two options.[19]

It would also be useful for the MRS need study to analyze the advantages and disadvantages of deferring a decision on post-1998 interim storage until 1990, when DOE is expected to recommend the first site for a repository. This would allow the decision to be made after: 1) evaluation of the results of the commercial spent fuel storage RD&D program required by NWPA, which is expected to be completed in 1989; 2) development of an integrated system model and evaluation of optimized integrated system designs; and 3) completion of characterization of the first round of candidate repository sites, at which time the projected schedule for repository availability would be much better known. If a decision were made to proceed with an MRS facility at that time, it could still be available by around 2001, the current target date for operation of full-scale facilities at the repository.

Finally, it would be useful for the MRS study to contain an analysis of the impact of storage options on the rate of progress in the repository program. As discussed in chapter 4, one of the major sources of resistance to efforts to provide a Federal storage facility in the past has been concern that the availability of such a facility would lead to deferral of the politically and financially costly steps involved in siting a geologic repository. In OTA's view, this is the principal programmatic risk in attempting to site and construct a large Federal storage facility before a permanent repository site is selected and licensed. The risk arises from: 1) the possibility that the effort to site and construct a Federal storage facility would divert resources and energy from the repository program; and 2) the fact that, once such a facility is available, it will be easier and less expensive to expand the storage capacity from year to year than to proceed rapidly to develop a geologic repository. (For further discussion of this point, see issue 1 in app. B.) On the other hand, some argue that making the Federal Government responsible for storing growing inventories of spent fuel would put more pressure on the Federal program to find a permanent solution. Because such considerations may be more important in an MRS decision than the relative technical merits of at-reactor vs. away-from-reactor facilities for interim storage, they are worthy of rigorous analysis in the MRS need study.

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[18] See chapter note at end of chapter.

[19] DOE comparisons of at-reactor and away-from-reactor storage to date have assumed that the at-reactor facilities would be financed at private utility borrowing rates, while the centralized facility would be financed at lower Federal borrowing rates and would not be subject to taxation. This biases the results in favor of away-from-reactor facilities.

Backup Waste Facility Plan

The other possible role of MRS facilities is as a long-term alternative to geologic repositories. A comprehensive Mission Plan must address the possible need for such an alternative. To date, no insurmountable technical obstacles to geologic disposal have been identified. However, there is always some possibility that major difficulties could lead to extended delays or even rejection of the concept. Thus, a complete specification of the Federal commitment to utilities must identify what will be done if that occurs. The principal question to be addressed is when to provide long-term alternatives to repositories so that the Federal Government can accept spent fuel in the event that geologic repositories are delayed for a long time. The answer to this question will determine the *backup waste facility plan*.

Generally speaking, only two alternatives will ensure that the Federal Government can take physical possession of waste or spent fuel from utilities if a geologic repository is delayed: 1) MRS facilities; or 2) disposal capacity based on some other disposal technology, such as subseabed emplacement. NWPA provides for the development of both options: section 141 requires the development of designs and construction plans for MRS facilities, and section 222 requires the accelerated development of alternative permanent disposal technologies.

If MRS facilities are provided for post-1998 interim storage, they would be available as long-term backup facilities if there are major problems with the disposal program. However, if it is decided to provide interim storage at reactor sites, a time may come when alternative facilities must be provided to prevent the spent fuel from remaining at the reactor sites indefinitely. Because the Act does not require or authorize construction and operation of such facilities, a comprehensive Mission Plan would identify a time at which DOE would address the question of whether to seek such authority from Congress and would discuss the criteria for making an affirmative decision.

To avoid the need for additional authority as long as possible, the proposed Mission Plan defers this decision until it is clear that there are major technical problems with geologic disposal. Specifically, it provides for the decision to be made after completing NWPA's mandatory process for siting two repositories, which will occur when NRC decides on the second site in 1998. This should provide ample time to obtain the evidence that might justify a reevaluation of the entire concept of geologic disposal. For example, rejection of one or more candidate sites during characterization, or even NRC disapproval of the first site submitted for licensing, would not be strong evidence that geologic disposal might not work, any more than drilling one or two dry holes on an otherwise promising potential oilfield proves that the field does not contain oil. Since there is little experience with at-depth characterization or licensing of a geologic disposal site, and since at least some geologists believe that it is impossible to tell on the basis of surface exploration alone whether a site is suitable for a repository, one can expect some "dry holes" before a site that can be licensed is found. On the other hand, if no such site can be found after completion of a conservative siting program designed to site two repositories (see discussion of the siting program below), ample grounds might exist for reevaluating the feasibility of geologic disposal.

If no proposed repository site has received a construction authorization by 1998, authorization to construct two MRS facilities (or alternative disposal facilities, if suitable technology is available) would be sought. Since DOE estimates that an MRS could be sited, licensed, and constructed in about 11 years after authorization, it should be possible to have backup facilities in operation between 2008 and 2012, the commitment dates for operation of the two geologic repositories, even if a decision to construct such facilities is not made until 1998. Operation of backup storage or disposal facilities with a capacity of 6,000 tonnes per year (DOE's reference loading rate for two MRS facilities), even if it came as late as 2012, could still assure that the spent fuel discharged by reactors now operating or under construction could be removed from the sites of most reactors (except a few of the oldest ones) within about 15 years after reactor shutdown. (See app. G.)

Deferring a decision on long-term alternatives until a full and fair effort has been made to site and license the geologic repositories required by NWPA has several advantages:

- *It avoids the risk that early availability of long-term storage facilities, or perhaps simply the effort to provide such facilities, might create pressures to defer difficult repository siting decisions, as discussed above.* While long-term MRS facilities might be constructed earlier, to allow more time for repository siting, it must be recognized that such a step may make it more difficult to procede with selection and evaluation of repository sites at all.
- *It provides ample time to develop backup technologies.* A conservative schedule for backup facilities allows time to test the feasibility of alternative disposal technologies and to develop MRS designs that are most suitable for use as a long-term alternative to geologic repositories. In this regard, it would be valuable for the MRS need and feasibility study to discuss the design criteria that would be appropriate for MRS facilities intended as long-term alternatives to geologic repositories, in contrast to those intended for relatively short-term interim or buffer storage, and to identify any RD&D needed to develop technologies for very long-term monitored storage. (This is discussed further in the analysis of the technology development program, below.)

IMPLEMENTATION PROGRAM

To be credible as a basis for contractual commitments with utilities, the proposed repository loading schedule requires not only allowances for delays, but also an implementation plan that contains measures to avoid delays in the first place and to mitigate the impact of difficulties that do occur.

As noted earlier, the key feature in the high-confidence implementation program described in this chapter is the use of backup sites and technologies, to give confidence that at least one acceptable combination of site and repository design will be available when needed even if some candidates are rejected. While this program emphasizes certainty rather than minimized front-end costs, it represents a *minimum* use of backups, since it involves using only one more candidate site and technology at key stages than the minimum required number. *It is a major conclusion of OTA's analysis that this minimum backup strategy can substantially increase confidence that the waste management plan can and will be carried out on schedule.*

Present Siting Program

The major source of uncertainty in the repository schedule lies in the process for finding suitable sites and for NRC review and approval of a repository constructed at those sites. Unlike many more familiar technologies, the site of a geologic repository is itself a central component of the technology. The natural barriers produced by the properties of the site are expected to provide the ultimate long-term insurance against any significant release of the waste. Thus, the process of finding sites with the right properties and of convincing NRC that those properties do exist is at the heart of the process of developing geologic repositories.

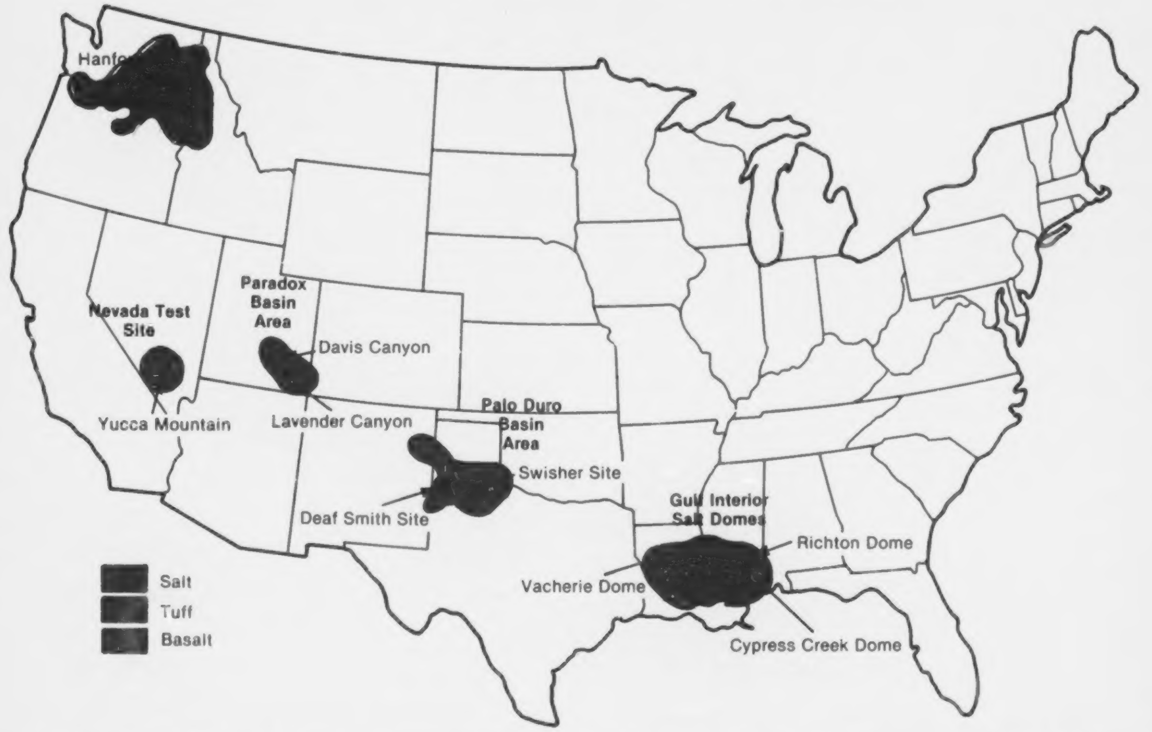
NWPA prescribes a detailed process for finding and licensing sites for two geologic repositories. The major steps are:

1. *Development of guidelines for site selection.* DOE, with NRC concurrence, issues general guidelines for recommending sites for repositories. This was accomplished in December 1984.
2. *Nomination.* Following issuance of guidelines, DOE must nominate at least five sites suitable for detailed evaluation for the first repository. This is anticipated in early 1985. No later than July 1, 1989, DOE must nominate five sites for the second repository.
3. *Characterization.* The crucial step in site evaluation involves tests performed in tunnels at the base of a large shaft excavated to the proposed depth of the repository. These tests are intended to determine the suitability of the site for a repository. Both NWPA and NRC regulations require DOE to characterize three nominated sites for each repository. The first sites are expected to be named in 1985.
4. *Presidential recommendation and congressional review.* Following characterization, the President must recommend to Congress a site for the first repository no later than March 31, 1987, and a site for the second repository no later than March 31, 1990. (DOE has concluded that these recommendations cannot be made until June 1990 and October 1995, respectively; see below.) At that time, the host State or Indian tribe has an opportunity to disapprove of the recommendation. Such disapproval prevents further development of the site unless Congress overrides it by passage of a joint resolution.
5. *NRC construction authorization.* If the site is not disapproved, it is submitted to NRC for review and issuance of a *construction authorization*—i.e., approval to proceed to construct a repository at the site. NRC must act on the DOE application within 3 years, which can be extended by one year at the Commission's discretion. This is the last step explicitly prescribed in detail in NWPA.
6. *Construction.* After NRC issues a construction authorization, DOE will construct the surface facilities and some portion of the underground facilities of the repository.
7. *Operating license.* NRC regulations prescribe that, following construction, NRC will review an application from DOE to begin disposing of waste at the repository, an application that will incorporate any new data about the site obtained during construction. If this license is granted, DOE can begin operation.

Imposing this detailed siting process and ambitious schedule on the ongoing DOE siting program raised certain concerns that need to be considered in the siting strategy. First, the 1998 deadline for initial repository operation can most likely be met only by using sites in areas that were already under investigation at the time the Act was passed, although full-scale operation of the first repository could be achieved by 2008 even if a site not now under consideration had to be used (see fig. 6-2). While this was recognized at the time NWPA was passed, some have questioned whether it is possible to apply the guidelines required by the Act fairly and effectively if the sites for initial consideration were already selected before the guidelines were developed. In addition, some are concerned that, because there is a wide variation in the quantity and quality of data available for the various sites under consideration, and because the siting guidelines were delayed nearly two years beyond the deadline specified by NWPA, it may not be possible to make a sound technical choice among the available sites at this time. Some are thus concerned that considerations other than technical ones might unduly influence the choices. They argue that DOE should postpone selecting sites for characterization until more information on the current sites can be obtained, or even until additional sites can be identified and evaluated.

Any major delay of site characterization (e.g., to allow new sites to be considered) would make it practically impossible to meet NWPA's 1998 deadline for the first repository. Thus, a Mission Plan based on the requirements of the Act must assume that the initial selection of sites for characterization will be made from among those now under consideration. The problem is how to proceed to the characterization stage while minimizing the risk that doing so would lead to premature decisions. *In fact, there is considerable agreement in the technical community that it is important to proceed now to detailed characteriza-*

Figure 6-2.—Potentially Acceptable Sites for the First Repository



NOTE: In December 1984, DOE published draft environmental assessments on these sites, indicating that the Hanford, Yucca Mountain, and Deaf Smith sites are the top three candidates for characterization.

SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program*, DOE/RW-0005 DRAFT, April 1984.

tion of specific sites in order to make progress in developing geologic disposal.[20] If that step is deferred because of concerns that there is not enough data now to proceed, the siting program might get caught in a vicious circle: before sites could be selected for at-depth characterization, much more data about the sites would have to be obtained; yet to get more data about the sites, characterization is necessary.

The principal risk in choosing sites for characterization using currently available data is that of prematurely discarding a site that in fact has a better chance of ultimately being licensed by NRC than one of the sites that is selected. Comparing sites will be a difficult task. Because there is no single generally accepted measure of the quality of a repository site, a judgment that one site is better than another must be based on a subjective balancing of many incommensurable factors. Such judgments will be particularly difficult before the data from in situ characterization are available, since the basic questions about site suitability can only be answered by at-depth testing. There is no assurance that the sites that appear most likely to be licensable on the basis of currently available information would turn out to be those that appear most favorable after characterization has been completed. *Carrying extra sites through critical stages of the site evaluation process would reduce the risk of pass-*

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[20] For example, the Interagency Review Group concluded that "there is an urgent need to obtain access to potential repository sites to begin the process of site characterization. Laboratory studies and in situ testing . . . cannot substitute for thorough examination of actual sites." *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste*, TID-28818 (draft), October 1978, p. 78. Similarly, a DOE/U.S. Geological Survey (USGS) study concluded that "The major impediment to the resolution of technical questions leading to the establishment of a mined geologic repository for commercial radioactive wastes is the lack of specific sites on which to conduct detailed in situ geological research." DOE and USGS, *Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository*, DOE/TIC-11033 (draft), April 1980, p. 1.

ing over a good site in favor of a less-favorable one by deferring the crucial decisions to screen out some sites in favor of others until more data are available. This approach will be discussed further in the following description and analysis of the proposed high-confidence siting strategy.

High-Confidence Siting Plan

A high-confidence Mission Plan, using only the authority now provided by NWPA, would use an expanded repository siting strategy to provide confidence that the two repositories required by NWPA would be available no later than required by the proposed loading schedule. Evaluation by OTA of DOE's analysis of possible sources of delay in the repository program[21] suggests that *there is considerable confidence that the target dates of 2008 and 2012 for full-scale operation of the first and second repositories can be met if one more site than the minimum required by law is carried through each stage of the siting process,* prior to the actual construction of each repository. Thus, four sites rather than three would be characterized, and two rather than one would be recommended for submission to NRC for construction authorizations.

Sources of Uncertainty

The effect of this expanded strategy on the level of confidence in the repository schedule can be seen by considering the two principal sources of uncertainty in the siting process:

- the time required to complete each stage of the siting process; and
- the likelihood of a site being rejected at each stage.

TIME REQUIRED TO COMPLETE EACH STAGE OF THE SITING PROCESS

Table 6-1 shows DOE's estimates of the possible range of times that might be required for each major stage of the siting process. *A strategy of carrying one more site than the required minimum through each stage provides insurance against the possibility that extended delays at any one site will delay the entire process.* For example, NWPA requires that characterization be completed at three sites before one can be recommended for licensing. If only three sites are characterized, then the date on which one can be recommended will be determined by the rate of progress at the slowest site. If four sites are characterized, one can be recommended as soon as the fastest three are completed; extended delays would have to be encountered at two sites to delay the entire process. Similarly, submitting two sites to NRC for licensing, rather than one, means that construction could proceed as soon as authorization is granted for either.

Table 6-2 shows how extra sites can reduce the risk that the entire process will be delayed by delays at one site. Notice, for example, that even if the likelihood of experiencing an extended delay at any one site during characterization is as low as 20 percent, there is about a 50 percent risk that at least one site will experience a delay that would hold up the site recommendation process. Characterizing four sites instead of three can reduce that risk to about 20 percent. In general, the largest improvement is provided by the first site added beyond the minimum number needed to proceed to the next stage. This finding is the basis for OTA's conclusion that a siting strategy using only one more than the minimum required number of sites at key steps can substantially increase confidence that large delays will be avoided.

LIKELIHOOD OF SITE REJECTION

Analysis performed for OTA indicates that there is a lack of consensus in the technical community about how much information about the ultimate suitability of a site can be determined at each stage of the site evaluation process—surface testing, in situ characterization, repository construction, and operation.[22] Some experts feel that a site that appears suitable on the basis of tests performed from the surface will have a high probability of being acceptable as a repository. Others believe that there could be as much as a 50 percent chance that such a site would be rejected on the basis of information obtained during characterization, and as much as a 40 percent chance that a site that survived characterization would subsequently be rejected on the

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[21] DOE, *Draft Mission Plan,* pp. 3-A-27—3-A-44.

[22] Ghovanlou et al., op. cit., ch. 8. Also published in Ghovanlou, et al., "Selecting a Repository Site," *Underground Space,* vol. 6, 1982, fig. 1, p. 244.

Table 6-1.—Possible Alternatives for Completion of Major Program Phases of First Repository

Recommend sites for characterization	Characterize sites	Select site and obtain site approval	NRC licensing review	Construct and test repository
Assumptions and schedule durations:			NRC adopts two-step construction authorization	Construction under two-step construction authorization
1-A Secretary recommends three sites to President by January 1985, President approves sites in minimum time provided by Act (15 months)	2-A Recommendation based on surface studies and ES construction data (22 months)	3-A President recommends site, no State or Indian Tribe disapproval (17 months)	4-A NRC review expedited (24 months)	5-A Phased construction, Phase One complete (53 months), Phase Two complete (90 months)
1-B NRC requires significant changes to siting guidelines, President approves site in minimum time provided by Act (21 months)	2-B Parallel permitting, in-situ testing (49 months)	3-B President recommends site, State or Indian Tribe disapproval filed, Congress overrides (20 months)	4-B NRC review takes nominal period allowed by the Act (36 months)	5-B Full scale repository (70 months)
1-C Extensive modification required to EAs, President approves site in minimum time provided by Act (27 months)	2-C Sequential permitting, in-situ testing (73 months)	3-C Additional DEIS review, President recommends site, State or Indian Tribe disapproval filed, Congress overrides (29 months)	4-C NRC requires additional review time as allowed by the Act (48 months)	5-C Phased construction, exploratory shafts not used for construction, Phase One complete (89 months), Phase Two complete (126 months)
1-D Secretary requires additional data to support site recommendation, President requires additional review period allowed by Act (45 months)	2-D Sequential permitting, ES construction delays, extensive in-situ testing (133 months)	3-D Additional DEIS review, President recommends site, site disapproved, select new site (43 months)	4-D NRC requires extensive additional information to support CA (60 months)	5-D Phased construction, exploratory shafts not used for construction, construction delays, Phase One complete (101 months), Phase Two complete (138 months)
			4-E NRC rejects site, new site selected, approved and CA issued (108 months)	

KEY: EA = environmental assessment
ES = exploratory shaft
DEIS = Draft Environmental Impact Statement
CA = construction authorization

SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program*, DOE/RW-0005 DRAFT, April 1984.

basis of information obtained during construction or operation.

The possibility that disqualifying data would be found after a site is recommended for licensing is of particular importance in view of current DOE siting plans. According to those plans, the initial license application would be based on 8 to 22 months of in situ testing (depending on the medium), while data from about 7 more years of at-depth tests, including 4 years of extensive underground construction, would be available before NRC is expected to act on the application for an operating license.[23] The shorter the time spent obtaining data prior to the license application, the greater the likelihood that any disqualifying problems at a site will not be discovered until after the application has been submitted.

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[23] DOE, *Draft Misson Plan*, p. 3-A-32, and fig. 3-A-5, p. 3-A-38.

Table 6-2.—Risk That Delay or Rejection of Sites in One Stage of Repository Development Will Delay Progress to the Next Stage

Sites needed to proceed to next stage	Number of sites considered at each stage 2	3	4	5
	P = 20%			
1	4%	1%	0.2%	.03%
2	36%	10%	3%	0.7%
3	NA	49%	18%	6%
	P = 50%			
1	25%	13%	6%	3%
2	75%	50%	31%	19%
3	NA	87%	69%	50%

NOTE: In this table, P represents the probability that any individual site would experience major difficulties in one stage of the siting process, either a delay in completing the process or outright disqualification. Since no site has ever gone through any of these stages, P is a subjective judgment. If N is the number of sites evaluated in the stage (columns) and K is the number of sites that must complete the stage to go to the next (rows), then the risk of a delay in the stage is simply the probability that at least N - K + 1 sites have difficulties. Using the simplifying assumptions that each site has the same probability (P) of experiencing difficulties, and that there is no interdependence of results among the sites, probability theory shows that the risk is given by the following statement:

$$\text{Risk} = \sum_{J=(N-K+1)}^{N} \frac{N!}{J!\,(N-J)!}\, p^{J}\,(1-p)^{(N-J)}$$

SOURCE: Office of Technology Assessment.

Because there is no experience in most of the steps for developing high-level waste repositories (and since final EPA performance criteria for repositories have not yet been adopted), this lack of consensus cannot be resolved at present and is a factor that must be considered in determining the appropriate approach for investigating sites for repository development. The expanded strategy described above reduces the consequences of rejection of any one site by providing an additional site as backup at each stage and by increasing the pool of viable sites. For example, if there is a 20 percent chance that any one site submitted for a construction authorization will be rejected by NRC, then submitting two sites instead of one reduces the risk of not having an approved site from about 20 percent to only 4 percent.

Characterizing four sites rather than three also provides insurance against a potentially important ambiguity in the requirements of NWPA. DOE considers that it can proceed to recommend a site for licensing even if one or more of the three sites to be characterized is found unsuitable during or after characterization.[24] However, DOE also recognizes the possibility that this interpretation of the requirements of NWPA might be found invalid, and that NWPA might be interpreted as requiring that before DOE can recommend a site for licensing, it must have three sites that appear suitable for a repository *after* characterization.[25] Table 6-2 clearly suggests that this more demanding interpretation would make the characterization stage much more vulnerable to delays if only three sites are characterized initially. For example, even a 20 percent probability that an individual site would be rejected would lead to a 50 percent risk that characterizing three candidate sites would produce fewer than three that were suitable after characterization. Characterizing four sites would reduce that risk to about 20 percent. If steps to characterize additional sites are not taken until this question can be resolved, which may not occur until DOE recommends a site, there is a risk of a delay of 4 or more years if the more demanding interpretation were upheld, and if it were necessary to find and characterize a replacement site for one rejected during the initial characterization phase.[26] In any case, if the legal uncertainty is not resolved before the end of the characterization process, and if fewer than three good sites are available at that time, there could be a delay of a year or more for consideration of a lawsuit to resolve the question.

Steps to Increase Confidence

The following section discusses the high-confidence siting strategy in more detail as it relates to each of four key areas:

- relationship of the siting processes for the two repositories required by NWPA;
- characterization of candidate sites for each repository;
- recommendation of sites to NRC for construction authorizations; and
- screening to identify new backup sites potentially suitable for characterization.

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[24] Ibid., p. 3-A-33.

[25] Recent discussions between DOE and NRC concluded that the issue remains to be resolved regarding how many sites need to be determined to be suitable after characterization. *The Radioactive Exchange*, vol. 3, No. 11, June 30, 1984, p. 1.

[26] DOE, *Draft Mission Plan*, p. 3-A-41. The *Draft Mission Plan* does not indicate an explicit plan for assuring that backup sites would be available.

HAVE TWO FULL, SEPARATE PROGRAMS FOR SITING A FIRST, WESTERN, REPOSITORY AND A SECOND, EASTERN, REPOSITORY

The overall goal of the siting program is to provide confidence that *two* repositories will be operating within a relatively short time of each other. Because the Act requires that transportation costs and impacts be taken into account in siting the second repository, the siting plan is also designed to maximize the likelihood that one repository would be located in the East and one in the West.

A clear commitment to a credible plan for siting both repositories may be needed to allay the concerns of those areas being considered for the first repository that they might by default wind up being the nation's only nuclear waste "dump" if financial and institutional pressures lead to indefinite deferral of the second repository. Since most of the sites under consideration for the first repository are in the West, a serious effort to site the second repository in the East, near most of the reactors, should help deal with concerns of the first round States about regional equity.

In this approach, the first round of site characterization—for the first repository—would contain only western sites. The eastern sites now under consideration would not be characterized in the first round.

For each round of site characterization to focus on one region, as proposed in the high-confidence siting plan, the first round must use western sites. Six of the nine sites now under consideration are located in the West (see fig. 6-2), and one of the two westernmost sites (in Nevada and Washington) *must* be included in the first round in order to meet NRC's requirement that at least one nonsalt site be characterized before the first repository site can be licensed (all of the other sites are in bedded or dome salt). Considering *only* the western sites in the first round, as proposed in this strategy, ensures that both the primary candidate for NRC licensing and its backup (explained later) would be western. In addition, it may be easier to reach agreement about the suitability of a site located in a relatively arid region the first time the licensing process is attempted. The six western sites now under consideration represent four distinct geohydrologic settings and three geologic media (basalt, tuff, and bedded salt), and thus should provide a sufficiently wide range of choices for characterization in the first round.

The second round of site characterization—for the second repository—would involve only eastern sites. Thus, sites characterized for the first, western, repository would not be considered again in the second round, as now contemplated by DOE. At present, the DOE *Draft Mission Plan* provides that one of the sites from the first round of characterization be counted among the three that must be characterized before the second repository is selected, as allowed (but not required) by NWPA.[27] DOE plans to characterize only two additional sites for the second round, and is currently screening crystalline rocks in the East to identify potential candidate sites (see fig. 6-3). The third site, to be carried over from the first round, most likely would be western, although it could be eastern if one of the eastern sites now under consideration were characterized in the first round.

Because OTA's high-confidence siting strategy provides for only western sites in the first round, they would not be used again in the second, eastern, round. Instead, DOE would evaluate four eastern sites before selecting the site for the second repository (unless the results of the first round of characterization show that three would give sufficient confidence that delays could be avoided). This approach would increase the chances that both a primary site and a backup (discussed below) for a second repository will be found in the East. It would also reduce the stakes involved in selecting the sites for the first round of characterization. If some sites from the first round are also used in the second, as now contemplated by the DOE *Draft Mission Plan,* sites selected for the first round face some chance of being selected for the second repository even though they are not the first choice for the first repository. Of course, there will always be some possibility that one of the sites from the first round of characterization would ultimately be needed for the second repository, but in this expanded siting plan that would be done only as a last resort, i.e. if a full and fair effort to find a suitable eastern site fails.

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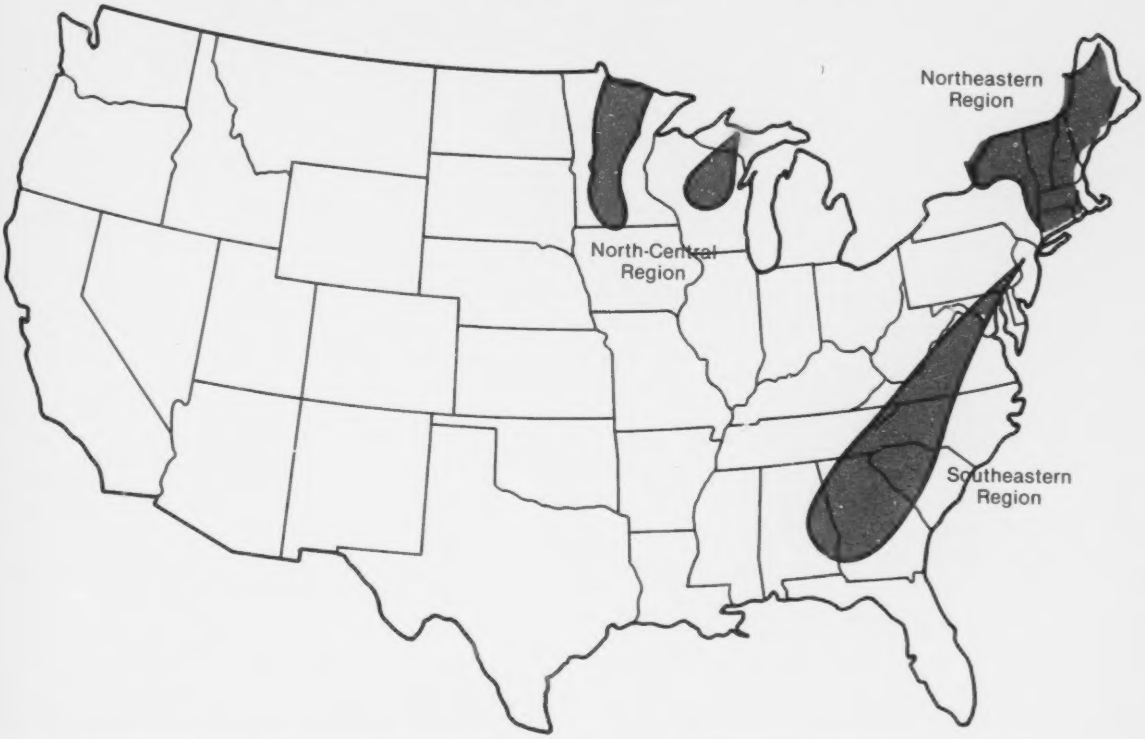
[27] DOE, *Draft Misson Plan*, p. 10-4.

Figure 6-3.—Regions Being Considered for the Second Repository



SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program*, DOE/RW-0005 DRAFT, April 1984.

CHARACTERIZE FOUR SITES FOR EACH REPOSITORY INSTEAD OF THE THREE REQUIRED BY NWPA

Characterizing more than the minimum required number of sites is the principal, and perhaps only, way to reduce substantially the likelihood of major delays or other complications at the crucial step of recommending the first site for a repository. Significant problems at this point could damage the credibility of the Federal waste management effort. Characterizing one more site than required by NWPA would provide insurance against the possibility of extended delays (see above). Characterizing four sites also gives greater confidence that at least two suitable ones will be available after characterization, allowing a backup to be submitted to NRC more quickly, as discussed below, and avoiding the delay of as much as 10 years that could occur if characterization of backups were not started until the principal candidate had been rejected.

The increased confidence that at least two suitable characterized sites would be available without extended delays also would reduce the risk that Congress might have to consider a State's objection to the President's recommendation of the first site without having a suitable alternative candidate available. In fact, NWPA requires DOE to recommend a second site for licensing for a repository within 1 year if the first recommendation is vetoed by the State and the veto is not overridden by Congress. This can only be done if a second suitable characterized site is available from among the first set of sites that are characterized.

Characterizing additional sites also reduces the risk that proceeding now to site characterization would prematurely narrow the available options on the basis of relatively little information. For example, characterizing four sites for the first repository allows one site to be selected from each of the four western geohydrologic settings. The decision about which settings to reject could be deferred until after a site in each setting had been characterized, so that the decision could be based on comparable and more extensive data from each site. This minimizes the risk that a site that has a better chance of ultimately being licensed by NRC might be passed over in favor of a less suitable site because the currently available data gives a misleading picture.

In this approach, the only narrowing of choices before characterization of sites for the first repository would be selection of one of the two sites under consideration in the Paradox Basin area and the Palo Duro Basin area, the western settings that each contain two sites. Comparing nearby sites in the same setting should be easier than comparing sites in substantially different settings. Thus, the first use of the siting guidelines would be in the relatively limited choice between sites in the same setting. The guidelines' major application would come at the later stage of selecting sites to recommend to NRC for licensing based on the data from site characterization, which are needed for the full application of the guidelines in any case.

Characterizing an extra site for each repository could increase total expected program costs by up to several percent. The actual amount would depend on the geologic medium involved and the extent of at-depth investigation required. This is discussed below.

RECOMMEND TWO SITES TO NRC FOR CONSTRUCTION AUTHORIZATIONS FOR EACH REPOSITORY, RATHER THAN JUST THE ONE REQUIRED BY NWPA

The conservative contractual commitment dates (2008 and 2012) for operation of full-scale facilities at two repositories allow for the possibility that the primary candidate sites will be rejected by NRC at some point during the licensing process. To give further confidence that the commitment dates will be met, a backup site for each repository would be submitted for a construction authorization as soon as possible after the primary site for each repository had been recommended. NRC would be asked to license both alternatives, rather than to choose between them.

If only one site per repository is recommended to NRC for licensing, then the selection of the final repository site must be made at the recommendation stage on the basis of only the information available after characterization. Recommending two sites per repository for licensing allows the final selection to be made after NRC's review of both sites, including review of the additional data that would be obtained from both sites during the 3 or more years of the licensing process.

The additional cost of submitting a second site per repository for licensing, assuming that two good sites are available after characterization, should be very small compared to the cost of characterizing the site in the first place. Furthermore, it would be inexpensive insurance against the delays that could result if licensing of a second site were not initiated until after the first was rejected. Even if neither site were rejected by NRC, this approach might still reduce the time required for the first repository to begin operation by allowing construction to begin as soon as either site for that repository is approved.

If both sites for a repository receive a construction authorization, the one not selected for development would be held as a backup in case problems are discovered during construction or during the first 5 to 10 years of operation of the repository at the primary site. If the backup site is not needed by the end of that period, it could be used for subsequent repositories beyond the first two.

When combined the first step, this step is designed to give confidence that DOE could recommend to NRC both a primary western site with a western backup, and a primary eastern site with an eastern backup. Separating the siting process into western and eastern rounds also reduces the risk that a good site from the first round that would otherwise be needed as a backup in that round would instead be needed for the second repository.

If either the primary site or the backup is rejected, another site would be submitted for a construction authorization as soon as possible to ensure that one backup would be available with minimum delay. If a suitable characterized site were available, the additional cost of submitting it for licensing would be small. If a suitable characterized site were not available, a contingency siting plan could provide for characterization of an additional site to be initiated immediately (see discussion of screening program for backup sites below).

CONTINUE SITE SCREENING TO IDENTIFY NEW SITES SUITABLE FOR CHARACTERIZATION AS BACKUPS FOR THE FIRST TWO ROUNDS

The preceding steps are intended to increase confidence in the repository schedule by increasing the number of sites initially considered at crucial stages of the siting process. However, there is always some possibility that even the increased number would not be sufficient and that, eventually, additional sites would have to be characterized. A high-confidence siting strategy would therefore include a backup site-screening program to identify additional new sites suitable for characterization for both the western and eastern repositories.

Characterization of an additional site could begin, for example, in the unlikely event that only one site survives the initial round of characterization and would ensure that a backup site for each repository can be recommended to NRC for a construction authorization. Or an additional site might be characterized in case one of the two sites submitted to NRC is rejected and there is no other suitable characterized site available. Such a step would minimize the delay that would result if the sole remaining site were rejected at some later point in the licensing process. (In either case, this would mean that all but one of the sites initially characterized had been rejected at some point in the process. This would be evidence that the more pessimistic view about the difficulty of finding suitable sites is correct, and that having a backup available is even more important than originally expected.)

This contingency siting plan increases confidence that the conservative contractual repository loading schedule can be met even if there are major problems with the first round of site characterization. As noted in the discussion of the repository loading schedule, it is possible that the first repository could be operating by 2008 even if none of the first four sites characterized proved suitable and one of the sites identified through the backup screening program had to be characterized and used. This contingency plan also gives added confidence that each of the two licensed repositories required by the Act will be backed up by a second site with a construction authorization, which could be developed into a full repository if problems are discovered with the operating repositories during their initial years of operation.

The backup site screening process would not replace the ongoing DOE siting program, which would continue as the means for meeting the schedules in NWPA for identifying the first candidate sites for characterization for the first and second repositories. DOE's analysis of the repository development schedule suggests that a siting program designed to make a best effort to meet the 1998 deadline for the first repository must proceed to site characterization in the next year or so. Yet it would probably take several years to identify new candidate sites and to complete the necessary procedural steps for characterizing them; for example, DOE does not expect to be able to begin characterizing sites for the second repository until 1989. Thus the NWPA repository schedule appears to require that characterization begin with the sites now under consideration, in order to determine if they include at least one that is suitable for a repository.

To give confidence that both a western and an eastern site can ultimately be found, the backup siting program would search for backups in the West for the western sites now under consideration for the first repository site, as well as backups in the East for the second site. This requires an expansion of the program in the DOE draft Mission Plan, which suggests that sites under consideration for the second repository be considered as backups for the first, if backups are needed.

The backup sites for possible characterization for a repository in the West could be obtained, for example, by continuing the screening of the Basin and Range province now being conducted by the U.S. Geological Survey (USGS).[28] This USGS effort uses a site screening process, proposed in 1980 by a Federal interagency working group,[29] that searches for favorable geohydrologic environments instead of focusing initially on particular host rocks or on federally owned land, as in past siting efforts.[30] (Identifying new sites that are not now under consideration for the first repository would avoid having to use as backups any of the current sites that were not judged good enough to be included among the first four selected for characterization, and would address the concerns of those who feel that siting efforts should not be limited to the current sites.) Backups for an eastern repository could be identified by using this same screening process in the East, or by considering media in addition to crystalline rocks, which are the focus of current efforts to identify sites for the second repository.[31]

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[28] M. S. Bedinger, et al., "Status of Geohydrologic Screening of the Basin and Range Province for Isolation of High-Level Radioactive Waste," in DOE, *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting,* pp. 193-195.

[29] U.S. Geological Survey, *Plan for Identification and Geological Characterization of Sites for Mined Radioactive Waste Repositories,* Water-Resources Investigations Open-File Report 80-686 (Reston, Va., May 1980).

[30] The siting program outlined in the *Draft Mission Plan* is a continuation of the two principal approaches to site identification that have been used in tha past by DOE and its predecessors: 1) search-

Costs and Benefits of the High-Confidence Siting Strategy

The basic issue in selecting a siting strategy is the balance between the initial cost of the strategy and the degree of confidence that long delays will be avoided. As noted earlier, OTA's conclusion that there can be considerable confidence in the conservative repository loading schedule is based on the assumption that the backup siting strategy described above would be used.

The crucial near-term siting question is whether to characterize one extra site for the first repository, in addition to the three required by NWPA. DOE's current plan to characterize only three sites is identical to the plan in place before NWPA imposed the 1998 deadline for initial repository operation. Characterizing one additional site is the principal significant expansion that could be made to increase the confidence that a licensed repository would be available by 1998. While characterizing an additional site would increase program costs over the next 4 years or so, it could reduce total program costs in the long run by reducing or avoiding potentially costly delays. Thus the decision on how many sites to characterize raises important questions for the Congressional appropriations process.

To give Congress a clear understanding of the implications of decisions about the siting program, especially the decision about how many sites to characterize, it would be valuable for the Mission Plan to present the results of a rigorous comparison of the costs and benefits of alternative siting strategies. This should evaluate both a minimum strategy that does no more than explicitly required by NWPA and an expanded strategy that includes one more than the minimum required number of sites at key stages. This comparison should consider: 1) the increased initial costs of a backup siting strategy, 2) the long-term cost savings that can result if delays can be avoided by such a strategy, and 3) the non-quantifiable costs and benefits of the siting strategy. The remainder of this section discusses some preliminary observations concerning each area.

INCREASED INITIAL COST

The principal cost impact results from the number of additional sites that would be characterized under the expanded siting strategy; the other provisions, such as submitting two sites for licensing, should have considerably less impact. The additional cost of characterization is difficult to determine at this time for several reasons. First, the actual cost of characterizing an additional site is difficult to determine from available information. It will depend upon the amount of work that must be done at the site. At one extreme, it is possible that preliminary borehole tests could lead to the site being rejected before an exploratory shaft is sunk.[32] At the other extreme, the *Draft Mission Plan* envisions carrying out at each characterized site a considerable amount of engineering and construction that is actually required only for a site that is recommended for development and licensing. While this can save some time in the repository schedule, it adds perhaps hundreds of millions of dollars to the costs incurred at the sites that are not used,[33] without in-

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ing for favorable locations containing a potentially suitable candidate host rock, and 2) searching for favorable locations with suitable host rocks on Federal reservations dedicated to nuclear activities. Of the six areas now under consideration for the first repository, four with salt deposits (Texas, Utah, Mississippi, and Louisiana) were identified by the first method, while two (the Hanford Reservation in Washington and the Nevada Test Site) were identified by the second. Candidate sites for the second repository are being identified by the first method, focusing on crystalline rocks (granite) in the East.

[31] DOE, *Draft Mission Plan*, pp. 2-46—2-47.

[32] Characterization can include boreholes from the surface as well as an exploratory shaft. If there is reason to suspect that additional tests from the surface might disclose factors that would preclude use of the site, those tests could be performed first to determine whether it is worth incurring the costs and impacts of sinking an exploratory shaft. If the site were rejected before the shaft was sunk, characterization activities could be terminated and the site reclaimed, as required by section 113(c) of NWPA.

[33] The DOE *Draft Mission Plan* proposes that characterization at each site include sinking two large shafts that can subsequently be used for repository construction (p. 3-A-21), a step which is expected

creasing the certainty of the schedule in the same way that characterizing an additional site would. To facilitate congressional deliberations on the DOE waste management budget, it would be useful for the Mission Plan: 1) to distinguish clearly between characterization costs that are required to determine which sites are suitable for recommendation, and those additional costs that are required only for a site which is selected for development; and 2) to compare DOE's current proposed approach with one in which four sites are characterized only to the extent necessary for DOE to select the most promising two for submission to NRC (as provided above), with the more expensive detailed work needed to support a license application to be done only at those two sites.

The additional cost is also uncertain because it is unclear how many extra sites would ultimately have to be characterized. At the outside, all of the steps described above could require characterization of three more sites than the five contemplated in current DOE plans (one extra site as a backup for each repository, and an additional eastern site to replace the one that DOE plans to carry over from the first round.) However, just as many additional sites might be required under a minimal strategy—if only one site survives the first round, for example, it would be necessary to characterize at least three new sites for the eastern repository. Thus, characterizing extra sites before they are needed, rather than after, merely incurs those costs earlier than would otherwise be the case. In addition, it may not be necessary to characterize more than three for the second repository in any case, if experience with the first round shows that an additional site is not needed to give the desired level of confidence in the schedule for the second repository.

REDUCED LONG-TERM COSTS

The major quantifiable benefit of the expanded siting strategy is that it can reduce the likelihood of the delays that would result if backup sites are developed only after it is certain that they are needed. Such delays would require additional interim spent fuel storage, for example—for this alone a delay of as much as 5 years, while additional sites were characterized, could cost between $600 million and $1.1 billion.[34] A rigorous comparison of the costs and benefits of alternative siting strategies must balance the expected costs of such delays against the expected initial siting costs.

NONQUANTIFIABLE COSTS AND BENEFITS

Perhaps the most important nonquantifiable benefit of the expanded siting strategy is that it reduces the risk that the credibility of the Federal waste management program would be damaged by major delays at key stages of the siting program, particularly at the crucial early step of recommending the first site for a repository. Because of its troubled history, the program does not appear to have a large reservoir of goodwill left to cushion it in the event of major difficulties in the future. From this perspective, it is important to compare siting strategies in terms of the risks they involve if siting turns out to be difficult, as well as the benefits they yield if siting proves to be relatively easy.

If the most optimistic view proves to be correct, the conservative siting strategy described in this section will produce more sites than are needed—which should increase confidence that repositories can be made available as needed if a significant expansion of the use of nuclear power is contemplated. Potentially suitable sites can be banked, saved for later use, and developed as they are needed. If the sites are eventually developed, the initial cost of site evaluation is not lost, only incurred sooner than absolutely necessary. If the more pessimistic view proves to be correct, the siting strategy will reduce the likelihood of costly delays and adverse political impacts that might result if the current siting

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to save about 3 years in the DOE schedule (p. 3-A-37). The additional cost of a second large shaft is estimated to be about $75 million to $100 million per site (footnote on p. 10-4). The *Draft Mission Plan* also provides for detailed engineering work including limited final waste package and repository designs for all characterized sites, including those not selected for development (p. 10-2). The additional cost of preparing limited final designs for all characterized sites is difficult to estimate but could amount to $160 million per site or more (table 10-1, p. 10-5, and fig. 3-A-5, p. 3-A-38). By comparison, NRC estimated in 1981 that $25 million to $30 million was an upper limit for the "at-depth" portion of site characterization (in soft rock), assuming that the test facility included two shafts and up to 1,000 feet of tunnels. U.S. Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures," *Federal Register*, vol. 46, No. 37, Feb. 25, 1981, p. 13973.

[34] Boeing Engineering Company Southeast, Inc., *Spent Fuel Storage System Options: A Comparative Cost Analysis*, a report prepared for the Electric Power Research Institute, 1984, table 2-5, p. 2-13.

process fails to produce enough suitable sites at any key decision point in the siting process. In addition, by providing for backups at key stages of the repository development process, the conservative siting strategy would increase the credibility of the process by reducing fears that crucial decisions might be prejudiced by the absence of any real alternatives.

It can be argued that expansion of the site evaluation process beyond the minimum required by NWPA would increase the political costs involved in locating radioactive waste repository sites, since it would increase the number of States affected by DOE siting activities. On the other hand, it can be argued that, because it would increase confidence that two repositories would in fact be available on schedule, with one in the East and one in the West, the expanded program would offer advantages to States that do not wish to see their nuclear reactors become de facto spent fuel repositories and to States that would be substantially affected by waste transportation if there were only one repository. Furthermore, keeping the processes for siting the first and second repositories separate, and not using sites characterized for one repository for the other as well, could reduce the concerns of the targets for the first repository that they would also be under consideration for the second, and the concerns of the targets for the second repository that they may wind up being the first—and perhaps the only—repository.

Waste Management Technology Development Program

The second element of a high-confidence implementation program is a *conservative waste management technology development program*. This program includes parallel development of both a *conservative baseline waste management system design,* intended to be widely viewed as workable despite the remaining technical uncertainties, and an *optimized system design*. The conservative baseline system design, to be widely viewed as workable, would be based on currently available data and on the assumption that current technical and regulatory uncertainties could be resolved in the direction of increased, rather than reduced, demands on system performance. This approach minimizes the probability that the design would have to be modified substantially in the light of unfavorable developments, and thus would build confidence that a conservative loading schedule based on the design could be met even if such developments occurred. It also provides a useful basis for a conservative estimate of disposal costs.

As noted earlier, the conservative design would be intended only for implementation during the demonstration phase of repository operation, while the optimized system design would be implemented for the operational phase. However, the conservative design would be available as a backup if problems are encountered with the alternative. Furthermore, the existence of a conservative design that is widely viewed as workable would reduce the likelihood that disagreements in the technical community, about whether a proposed "optimal" design is suitable, would be interpreted by the public as disagreement about whether there is *any* design that will work.

This section will describe in general terms both a conservative baseline design and the related RD&D program for each element of the waste management system.

Geologic Repositories

NWPA requires that a conceptual repository design be included in the site characterization plan to be prepared for each site proposed for detailed evaluation. In addition, baseline repository designs are needed as a basis for determining the waste disposal fee and to provide additional focus for the RD&D program.

DOE and its predecessors have generally used the approach of developing reference repository designs that appeared most cost effective in light of the best information available at the time. As new information about site conditions, waste characteristics, repository performance, or regulatory requirements became available, the designs were modified to conform to the new information and to maintain their cost effectiveness. This has sometimes led to ongoing technical disagreements about whether the designs would be acceptable, and to repeated changes in the system design. The object of developing a conservative baseline design is to minimize the technical debates about whether the system would be able to meet regulatory requirements, and to provide a basis for a workable disposal system that is not likely to require continued modification.

One risk of using conservative baseline designs is that they could lead to higher waste disposal costs than necessary if additional RD&D indicated that their conservatism was excessive but it proved institutionally difficult to relax that conservatism once the designs had been adopted. This risk would be reduced by proving for a demonstration phase of low-level operation at the first repository before the full-scale packaging and handling facilities are built. The conservative system design is in fact explicitly intended for that initial demonstration phase, with development of an optimized full-scale system design deferred until the principal remaining technical uncertainties have been resolved.

Using a conservative design for the demonstration phase should reduce the likelihood of difficulties during the licensing process, and could minimize the time required to gain NRC approval for initial emplacement of waste in the repository. Until the final design is completed, the conservative reference design could be used as a basis for a conservative estimate of the waste disposal fee, thus reducing the likelihood of insufficient revenues. It should be noted, however, that even if a conservative design must ultimately be used, the additional costs should not substantially affect the overall economic competitiveness of nuclear power.[35]

The principal areas for conservatism in repository designs are reduced thermal loading, retrievability, the waste form, and the waste package.

REDUCED THERMAL LOADING

A major source of conservatism in repository design would be in thermal design criteria—allowable heat load per acre and maximum temperatures of waste package and rock formation. The decay heat from the waste is a major source of uncertainty about the long-term behavior of the engineered barriers, the repository facility itself, and the hydrogeologic environment in the vicinity of the repository. One straightforward way to reduce technical uncertainties about repository performance is to keep the repository temperatures relatively low.[36] Available studies suggest that a conservative initial repository design would keep the maximum temperature of the rock in the repository in the vicinity of 100° C. For example, a recent National Research Council review of geologic disposal concluded that limiting the rock temperature to 100° C would provide confidence in the suitability of borosilicate glass, the reference waste form for reprocessed waste, until the necessary research is performed to show that it would be suitable at higher temperatures.[37] In contrast, current DOE reference designs have rock temperatures that range from 140° C (in unsaturated tuff) to 250° C (in basalt).[38] In addition to reducing technical disagreement about the expected performance of the repository, use of conservative thermal criteria may have the added benefit of reducing the amount of RD&D that is needed on waste forms and packages by reducing the temperature range for which their performance must be assured.

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[35] A review of the papers presented at a recent international conference on radioactive waste management concluded: "Though (disposal) costs are higher than had been assumed previously, they do not seem likely to have a serious or decisive impact on the use of nuclear power—and this even in countries with small nuclear programmes. Economics was not and will not be a major driving force for simplifying or reducing conservatism in radioactive waste management systems; elaborate systems that meet long-term safety and stringent radiation protection requirements can be afforded, even though they may not always be justifiable on technical grounds." S. Fareeduddin and J. Hirling, "The Radioactive Waste Management Conference," *International Atomic Energy Agency Bulletin*, vol. 25, no. 4, December 1983, p. 4. For perspective, DOE projects that the price of uranium in the year 2000 might range somewhere between $25 and $120 per pound (in current 1983 dollars), compared to a price of about $20 per pound in 1984, and that an increase of $10 per pound in the price of uranium increases the nuclear fuel cost to utilities by about 0.8 mills (.08 cents) per kilowatt-hour (kWh). U.S. Department of Energy, *United States Mining and Milling Industry: A Comprehensive Review*, DOE/S-0028, May 1984, pp. 47 and 60. This range of uncertainty represents a range of about 8 mills/kWh in nuclear fuel cost (measured in 1983 dollars), compared to the 1 mill/kWh waste disposal fee established by NWPA.

[36] For example, in its comments on DOE's preliminary draft Mission Plan, NRC observed that "DOE can reduce or eliminate uncertainties about testing needs by design measures such as limiting thermal loading." Letter from John G. Davis, Director, Office of Nuclear Materials Safety and Safeguards, U.S. Nuclear Regulatory Commission, to Michael J. Lawrence, Acting Director, Office of Civilian Radioactive Waste Management, Department of Energy, Feb. 8, 1984, p. 2.

[37] *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes*, (Washington, D.C.: National Academy Press, 1983), p. 7. Conservative repository designs developed by the Swedish utilities would also limit maximum temperatures to this range. See, for example, KBS, *Final Storage of Spent Nuclear Fuel—KBS-3*, (Stockholm: Swedish Nuclear Fuel Supply Co., May 1983).

[38] National Research Council, op. cit. p. 8.

A lower thermal loading can be achieved in three ways:

1. *Cooling the waste prior to final sealing in the repository.* Even with an optimistic repository loading schedule, with the full-scale facilities of the two repositories beginning operation in 1998 and 2005, the initial spent fuel emplaced would be 25 years old, and fuel as young as 10 years old would not be emplaced until after 2010.[39] Additional cooling could be obtained, if desired, by storing the spent fuel above ground at the repository site for a longer period before emplacement, or by keeping the repository rooms open for some period after emplacement and using active ventilation to remove heat before the rooms are backfilled and sealed.
2. *Reducing the amount of waste in each canister.* The amount of waste placed in each canister affects not only the maximum temperature of the canister after emplacement, but also the number of canisters that must be handled each year to accommodate a target waste loading rate, an important determinant of system design and cost. Recent DOE designs assume that the canister loading will be increased by disassembling spent fuel assemblies and consolidating the individual rods in the waste canister, allowing the rods from 6 pressurized water reactor assemblies, or 18 of the smaller assemblies from boiling water reactors, to be placed in a single canister. Since this involves an additional complex operation, a conservative design (for demonstration phase operations and initial cost estimates) would instead assume no rod consolidation. The RD&D program for developing an optimum system design would be intended to provide the data needed to justify larger canister loads.
3. *Reducing the amount of waste per acre of repository.* Reducing the amount of waste per acre (the emplacement density) will reduce the heat load per acre for waste of any given age, leading to lower temperatures. At the same time, it would increase the number or size of repositories required for a given amount of radioactive material, thus increasing the disposal cost. From a technical point of view, increasing the emplacement density is an easy way to relax the thermal conservatism used in the demonstration phase.

Using conservative thermal criteria for the baseline repository design is consistent with the principle of basing the baseline design to the maximum extent possible on data and analysis that are available now. The National Research Council study of geologic disposal concluded that current DOE design temperatures are much higher than the temperatures used in most studies of waste form dissolution,[40] and it suggested using conservative initial temperature limits, although it also concluded that research will probably eventually allow use of higher temperatures. While conservative thermal criteria would be used for initial emplacement of waste during the demonstration phase, the RD&D program would determine the extent to which those criteria could be relaxed for emplacement during the operational phase.

RETRIEVABILITY

NRC's regulations for high-level waste disposal require that the repository design keep open the option of waste retrieval throughout the period during which wastes are being emplaced, and thereafter until completion of a repository performance confirmation program and NRC review of the results. The regulations specify that the design provide for retrieval to be undertaken any time within 50 years after initiation of emplacement, subject to modification in light of the planned emplacement schedule and confirmation program.[41] In addition, NWPA (sec. 122) also requires that repository designs allow for retrieval of spent fuel for safety or economic reasons, subject to NRC approval.

An important design question affecting the cost of disposal is whether to provide for "ready retrievability," easy access to the waste, by keeping the repository rooms open during the retrievability period rather than backfilling them soon after waste emplacement. A period of ready retrievability offers two advantages. First, it reduces concerns that emplacement of waste in a repository is a practically irreversible step. Second, it enables economic recovery of spent fuel if reprocessing appears desirable after the fuel has been emplaced.

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[39] U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* DOE/RW-0006, September 1984, fig. C.2, p. 284.

[40] National Research Council, op. cit. p. 8.

[41] *Federal Register,* vol. 48, No. 120, June 21, 1983, p. 28197.

NRC's regulations do not require easy access, nor do they preclude backfilling. While there are some advantages to early backfilling, particularly in salt, remining the hot backfill to retrieve the waste could be quite difficult and expensive.[42] Thus, the retrievability requirement may be an additional factor favoring conservative thermal design criteria.

Since the design implications of the NRC requirement have not yet been thoroughly assessed, a conservative initial design would provide for some period of ready retrievability after emplacement, although perhaps not for the full period of repository operation. DOE has analyzed 25-year ready retrievability and concluded that it is feasible, although it is more expensive because it requires reduced thermal loads per acre.[43] However, the additional cost could be reduced by using ventilation to remove excess heat; furthermore, the conservative thermal loads needed to meet a 100° C design temperature may enable ready retrievability at relatively small additional cost.

In any case, the assumption of some period of ready retrievability should provide a conservative estimate of the cost of disposal and could increase confidence in initial low-level emplacement of waste in the repository. The assumption could be relaxed for full-scale operation when analysis is available to show that NRC requirements can be met even if rooms are backfilled soon after waste emplacement, and when it is clear that ready retrievability of spent fuel is not needed for economic reasons.

WASTE FORM

DOE reference waste forms are borosilicate glass for solidified high-level waste and untreated fuel assemblies for spent fuel. Because EPA analysis concludes that either waste form could meet EPA's proposed environmental standards,[44] and because these are the two waste forms that have been studied in most detail, a conservative baseline system design would be based on these waste forms. This is consistent with the decision to use borosilicate glass as the waste form for solidifying the liquid commercial high-level waste stored at the inoperative Nuclear Fuel Services reprocessing plant at West Valley, NY, and the defense high-level waste stored at the Savannah River plant. The glassified waste from West Valley, and some of the waste from Savannah River (if it is decided to place defense waste in commercial repositories), could be used in the demonstration phase of the first repository, along with an amount of spent fuel. As noted above, a National Research Council study concluded that keeping the temperature of the borosilicate glass below 100° C, as provided in the conservative repository design for the demonstration phase, would give confidence in its suitability as a waste form until the uncertainties in its performance at higher temperatures can be resolved through additional research.[45] The waste form RD&D program would determine whether this conservatism could be relaxed in the full-scale operational phase.

The RD&D program would provide for development of backup waste forms for both untreated spent fuel and high-level waste as a hedge against unforeseen problems such as regulatory difficulties. In particular, the recent National Research Council study of geologic disposal concludes that neither waste form may be able to meet NRC's criterion that the engineered barriers allow no more than one part in 100,000 of each critical radionuclide to escape each year.[46] While this criterion is not absolute, and might be adjusted by NRC for individual radionuclides in light of the EPA standard or the geochemical characteristics of the repository and its environs,[47] it is possible that less soluble waste forms might be necessary for at least some candidate repository sites. In addition, the National Research Council study concluded that significant improvements in repository performance could be achieved if highly insoluble waste forms could be developed. The study participants recommended a backup technical program that would: 1) provide insurance against the contingency that release rates from currently preferred waste forms prove considerably higher than now estimated, and 2) develop better waste package alternatives that could be used in later stages of waste emplacement.[48] The potential effect of a reduced waste form release rate on the risks from geologic disposal is shown in table 6-3.

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[42] National Research Council, op. cit., p. 9.

[43] The cost impact is greatest for a repository in salt, because, unlike hard rock, salt flows under pressure, making it more difficult to keep tunnels open for an extended period. U.S. Department of Energy, *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste*, DOE/EIS-0046F, (Washington, D.C.: October 1980), vol. 2, app. K, pp. K.23-K.25.

[44] U.S. Environmental Protection Agency, *Draft Environmental Impact Statement for 40 CFR 191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, EPA 520/1-82-025, (Washington, D.C.: December 1982).

[45] National Research Council, op. cit., p. 7. This study concluded that "borosilicate glass is the appropriate choice for further testing and for use in current repository designs" but also that "there are uncertainties about its performance in a repository that need to be better understood before glass waste would be acceptable for emplacement in a repository." Ibid., p. 78.

[46] National Research Council, op. cit., pp. 237-238.

The RD&D program could examine such waste forms, as well as processes for treating spent fuel (e.g., by powdering or chemical dissolution) so that it could be incorporated in such a waste form directly if reprocessing and plutonium separation is not otherwise undertaken for resource recovery reasons. However, later decisions about whether to use an alternative waste form that involves significantly more complex treatment and handling processes than the reference waste forms involve (e.g., dissolution and resolidification of spent fuel) should take into account the increased costs, risks, and operational exposures that would be entailed.[49] Conservatism also suggests that the entire waste management process be kept as simple as possible.

WASTE PACKAGE

A conservative baseline waste package would use the package design that has received the most study to date: a metal canister, containing several spent fuel assemblies, which would be emplaced in vertical boreholes drilled in the floor of the repository rooms. Since the package would be unshielded, it would require remote handling. Potentially more cost-effective emplacement techniques now under consideration by DOE, such as insertion into long horizontal boreholes drilled out from the walls of the rooms, would not be used in the baseline design because they have not been studied as thoroughly as the vertical emplacement concept.

A major aspect of conservatism in the waste package concerns the design lifetime of the package. Proposed EPA criteria encourage use of multiple barriers to increase confidence about long-term isolation, and NRC's final regulations require that the waste package provide assurance of containment of the waste for a period of from 300 to 1000 years, the period during which the heat released by the waste will have its greatest effect. Some argue that analyses using mathematical models to project repository performance show that such a package would not significantly improve the predicted per-

Table 6-3.—Effects of Canister Life and Waste Form Release Rate on Projected Population Risks Over 10,000 Years

	Projected health effects		
	Granite	Bedded salt	Basalt
Canister life:			
Reference Case (100 years)	—	190	—
(500 years)	760	—	4,400
1,000 years	575	90	3,900
5,000 years	120	40	180
Waste form release rate:			
Reference case (10^{-4}/year)	760	190	4,400
High estimate (10^{-2}/year)	2,500	200	18,000
Low estimate (10^{-6}/year)	10	50	50

— = Not applicable.

SOURCE: U.S. Environmental Protection Agency, *Draft Environmental Impact Statement on 40 CFR Part 191, Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes,* EPA 520/1-82-025, December 1982.

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[47] 10 CFR Part 60.113(a)(1)(ii)(B).

[48] National Research Council, op. cit., pp. 82-83.

[49] The National Research Council review of geologic disposal observed that the operational considerations of producing different waste forms could be a factor in the choice between waste forms, and concluded: "The analysis of the release of radioactivity to the environment must include the entire waste disposal cycle, beginning with waste-form manufacture, to achieve overall minimal release objectives." National Research Council, op. cit., p. 14

formance. Others, including NRC, argue that it may be needed to give greater confidence in the predictions of repository performance.[50]

A conservative approach would be to provide for a waste package with a design life exceeding the regulatory requirements, and to use that waste form as a fully redundant barrier, rather than as a compensation for any defects in the geologic features of the site. (The potential effect of increased canister life on the risks from geologic disposal is shown in table 6-3.) Long life is achieved by using thick canister walls and/or corrosion-resistant material, such as copper, titanium, or zirconium. For example, a Swedish-designed copper canister for use in a granite repository has been estimated to have up to a 1-million-year life.[51] DOE estimates that a titanium canister would add about $6 per kilogram to the cost of disposal,[52] compared to current waste package designs using a simple canister of stainless steel (for tuff) or carbon steel (for salt or basalt).[53] A conservative baseline system design would include a long-lived package in its plans for the demonstration phase and in estimating disposal costs, while the RD&D program to develop an optimized design would determine whether that conservatism could be relaxed for full-scale operation.

While the conservative baseline design would use the borehole waste package concept, recent analyses have suggested that there may be significant advantages to a waste package design that is significantly different from the borehole design. This alternative design involves a massive (70 to 100 tonnes) cast iron or cast steel cask holding up to 10 to 20 tonnes of spent fuel, which could also conceivably be used for storage and transportation.[54] Such a cask would provide radiation shielding so that complicated hot cell operations, shielded transport vehicles, and shielded storage vaults would not be required.[55] The casks would simply be placed in repository rooms, eliminating the need for drilling holes for holding the package.

It may be possible to design such a cask as a universal container for storage, transportation, and disposal. If so, it could substantially reduce the complexity of the waste management process and reduce worker exposures, since the spent fuel would be handled directly only once—at the time it is placed in casks at the reactor. This universal container would also provide great flexibility in the system, since once spent fuel has been placed in the cask in which it will ultimately be buried (unless it is removed for reprocessing), slippages in the repository schedule would not cause additional storage problems. Even if such a multipurpose outer cask cannot be used, the universal container concept could be applied to an inner container that could be inserted into separate outer containers for storage, transportation, and disposal.

Because of the potential advantages of this unproven concept, the RD&D program to develop an optimized system design would resolve questions about its feasibility as quickly as possible, so that this concept can be considered as an option for the operational phase of the first repository. (It is important to resolve the question before full-scale packaging facilities are designed and constructed, because the different waste packages impose different requirements on the design of the handling facilities and on the repository itself. The operational implications of using a massive disposal cask may have to be determined during the generic packaging and handling test program, required by the Act, before a decision could be made to adopt that concept.) Although DOE plans to examine this system, it is unclear from the *Draft Mission Plan* whether this system's feasibility would be determined in time for its use in the full-scale facilities of the first repository. As discussed above, the two-phase approach to operation of the first repository is designed to allow ample time to determine whether this technology is feasible and desirable before a commitment is made to a final design for the operational-phase system.

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[50] 10 CFR Part 60.113(a)(1)(ii)(B). The importance of an effective engineered barrier in addition to the waste form itself is discussed in "Achieving Performance Objectives for the Engineered Barrier System," a Staff Report prepared by the Subcommittee on Energy Conservation and Power of the Committee on Energy and Commerce of the U.S. House of Representatives, Committee Print 98-II, November 1984.

[51] National Research Council, *A Review of the Swedish KBS-3 Plan for Final Storage of Spent Nuclear Fuel* (Washington, D.C.: National Academy Press, 1984), p. 3.

[52] DOE, *Report on Financing the Disposal of Spent Fuel,* p. 23.

[53] DOE, *Draft Mission Plan,* p. 3-A-19.

[54] Westinghouse, *Engineered Waste Package*; Hoskins, op. cit.

[55] Westinghouse, *Engineered Waste Package,* p. 279.

TECHNOLOGY OF PREDICTION

As discussed in chapter 3, predictions of repository performance will be based heavily on the use of mathematical models. Use of such predictive techniques in a formal licensing process may well be one of the most difficult aspects of demonstrating disposal, and validation of those techniques will be of critical importance.[56] Since such long-term prediction has never been done in a formal regulatory process, many unforeseen problems will probably be encountered the first time it is attempted. A serious effort to anticipate and resolve such problems before the first formal licensing proceeding commences could avoid unnecessary delays at that critical stage of the waste disposal program. This could be accomplished, for example, if the site characterization plan required by section 113(b) of NWPA included a preliminary analysis by DOE of the expected performance of the conceptual repository design for that site, based on the data available prior to characterization. If this analysis were explicitly related to NRC and EPA performance requirements, a broad review process involving NRC, EPA, USGS, and others could begin at that time. This could allow ample time for thorough consideration of the issues that might arise. It would also provide a rigorous basis for the characterization program, so that efforts could be focused on resolving the uncertainties that were identified as centrally important to the predictions of repository performance.

While this approach might not lead to formal resolution of licensing issues, in the sense that they could not be reopened later, it is possible that a sufficient degree of technical consensus could be reached that some issues would be effectively resolved. This would permit attention to be focused on those issues that remained in dispute. If this were done at each site recommended for characterization, it should increase the probability that NRC would be able to reach a decision on a site within the 4 years' maximum time allowed in NWPA.

Storage

Available analyses indicate that there are technically promising interim storage methods that could substantially reduce the overall cost of waste management. These include rod consolidation and storage casks that could also be used for transportation and perhaps for disposal. Since these methods have not yet been demonstrated and licensed, a conservative system design would not assume that these technologies would be available, but would instead assume that all spent fuel would be received unconsolidated in casks optimized for shipping only. However, the RD&D program in the Mission Plan would contain an accelerated effort to examine these possibilities and determine the extent to which they could be incorporated into a later revision of the system design. It is important that this be resolved as quickly as possible, before final choices about interim storage systems are made by individual utilities (in deciding how to deal with their spent fuel until at least 1998) and by Congress (in deciding whether to authorize MRS facilities after the MRS proposal is presented in 1985). Because these decisions could be strongly affected by the availability of a multipurpose cask or other form of universal container, the Mission Plan should clearly show the relationship between the program for evaluating the feasibility of such containers and the timing of the storage decisions that would be affected by their availability.

The RD&D program must also address the technology requirements for monitored storage for indefinite periods. The storage technologies that are most mature today, and that would most likely be selected for an MRS facility if one were to be built in the 1990's, are the surface cask and drywell concepts.[57] While these are particularly well suited for providing easily expandable storage capacity in the face of an uncertain level of demand (as would be the case for buffer storage to deal with small schedule slippages), they may not be optimal for providing large amounts of storage for an extended period in the event of major difficulties in the repository program—the principal role for MRS facilities in the backup facility plan described above. In addition, storage facilities designed for a long and perhaps indefinite period of storage may raise licensing issues that are not faced by facilities intended for a limited period of interim storage. Thus the RD&D program in the Mission Plan would include a program for developing, testing, and perhaps demonstrating appropriate storage technologies so that a reliable long-term system can be provided with high assurance of success if needed.

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[56] The National Research Council study of geologic disposal noted that "There is not yet a validated technique for predicting the performance of borosilicate glass—or of any other waste form—in a repository . . . Whatever technique the U.S. Department of Energy (DOE) adopts for predicting waste-form and waste-package performance must be carefully validated before any waste form and waste package can be considered acceptable." National Research Council, *Isolation System*, pp. 78-79. For a discussion of general issues in the development and use of predictive models, see Office of Technology Assessment, *Use of Models for Water Resource Management, Planning, and Policy*, OTA-O-159, August 1982, ch. 3.

[57] DOE, *Draft Mission Plan*, p. 3-B-7.

Transportation System

A conservative baseline system design would assume that transportation during full-scale operation of the repository system would be accomplished with casks that are designed for transportation only and that are optimized for the repository loading schedule, taking into account the age of spent fuel or high-level waste at the time it would be transported to a repository. As noted in chapter 3, designing the casks for fuel that is at least 10 years old would provide an additional margin of conservatism by reducing the effects of self-heating in case of transportation accidents involving a fire. There is little question that such casks can be designed, licensed, and constructed in time for the conservative loading plan, although any transportation during the next decade or so would probably have to use the existing generation of casks. While detailed designs remain to be developed, currently available analysis should give a solid basis for initial estimates of cost and capacity.

The transportation section of the Mission Plan would also include a baseline reactor storage unloading plan, since that will have significant implications for transportation. For example, an unloading plan that provides for large amounts of stored spent fuel to be removed from a relatively small number of reactors each year, rather than for smaller amounts from a larger number of reactors, may simplify the transportation process and reduce its costs and impacts by allowing the use of dedicated unit trains. However, it would also require allowing larger quantities of spent fuel to build up at each reactor site before the site is unloaded. (See app. G for a discussion of the limitations on the rate at which spent fuel can be removed from reactor sites.) A conservative initial Mission Plan would assume that interim spent fuel storage would be unloaded according to the "oldest fuel first" principle included in the reference contract adopted by DOE. Assuming that all spent fuel is to be shipped by truck would maximize the number of shipments and the demands on the repository waste receiving facility as a basis for a conservative estimate of system costs and impacts.

One important focus of the transportation RD&D program is to determine whether casks that might be used for storage and/or disposal can be designed to be suitable for transportation as well. As noted earlier, this could greatly simplify the overall waste management process. This will require substantial coordination with the spent fuel storage and repository development programs to ensure that a fully integrated optimized system design can be developed in time to be considered for the operational phase of the first repository.

Packaging and Handling Technology

To ensure that unforeseen bottlenecks do not prevent the Federal Government from accepting waste according to the planned schedule, prior experience at handling, packaging, and emplacing radioactive waste at operational rates would be valuable. DOE now estimates that by the time a repository is to begin operation in January 1998 some 36,000 tonnes of spent fuel, representing over 126,000 individual spent fuel assemblies, will have been discharged by commercial nuclear reactors.[58] To store or dispose of this spent fuel at a central facility fast enough to stop the further buildup of inventories in at-reactor storage in 1998, without even beginning to work off the backlogs, would require handling about 2,300 tonnes, or about 7,900 assemblies, in 1998 alone. If this spent fuel were being canned for storage or disposal, it would require filling, sealing, and testing—using remote handling procedures—up to 5,000 canisters per year (depending on the final system design).

There is experience with all of the procedures for handling spent fuel through the step of canning for storage, but there is no experience at rates approaching those that must be achieved for full-scale operation. For example, DOE tests involving emplacement of encapsulated spent fuel in a deep mined facility in granite at the Nevada Test Site have used only 11 spent fuel assemblies. Furthermore, there is no experience with the procedures that might be required for final packaging of either spent fuel or high-level waste for permanent disposal, procedures that may be more complex than those required for canning for temporary storage. While there is little doubt that waste can be packaged and loaded at relatively high rates, there is less certainty about the rates that could actually be achieved by the first facilities designed for that purpose.

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[58] These are DOE's most current projections, found in *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, September 1984, ch. 1.

The provisions of NWPA suggest a conservative RD&D program that could give a high degree of assurance that full-scale facilities will operate at the planned rates and thus minimize the risk that commitments to delivery schedules cannot be met. The program would involve three stages prior to full-scale repository operation, allowing development of hands-on experience with large amounts of spent fuel and/or high-level waste in a series of steps extending over the next 20 years. The first stage would take place before the first site is approved, while the next two would take place at the site following NRC approval.

GENERIC TESTS

The first stage would involve the generic packaging, handling, and emplacement tests required by section 217(d) of NWPA. Since many of the operational questions apply to large-scale storage as well as to disposal, it may be very useful to plan for an integrated storage and disposal operational testing program that could provide data useful to MRS designs, as well. The program could also include the 300-tonne dry storage R&D program authorized in section 218(c). Such a program would develop packaging and handling technology that would allow the packaged material to be emplaced either in surface storage or into a repository. This would help ensure that spent fuel or high-level waste could be accepted at operational rates at a repository on a target date, even if it were decided to defer full-scale loading of the repository itself. As noted above, handling and emplacement tests may be a particularly important part of determining the feasibility of using very large self-shielded casks for disposal and would also be useful in developing final designs for handling such large casks at operational rates even if the casks are only used for surface storage.

An integrated storage and disposal test facility would also allow the development and demonstration of the capacity to retrieve waste from a repository at a rate comparable to the emplacement rate—an NRC requirement—and to place it into temporary surface storage if necessary. This should help build confidence that initial emplacement of waste into a repository is not an irreversible step.

To gain needed operational experience might require a substantial quantity of spent fuel or high-level waste. For example, tests at a scale of 5 percent of both the total capacity and projected annual handling rate of DOE's current reference repository design could require over 1,000 tonnes over the next decade. The actual amount that should be used would be determined by an analysis of: a) the need for reliable data and experience concerning operations with highly radioactive materials over a sustained period, and b) the need for packaged waste or spent fuel for use in the second stage of preoperational tests, early tests of waste emplacement in a repository during the demonstration phase of repository operation.

It may be possible to conduct all of the needed generic operational tests using existing government facilities. If not, NWPA authorizes construction of a test and evaluation facility (TEF) that could allow unlicensed temporary emplacement of up to 100 tonnes of spent fuel in a repository-like facility at anticipated repository depths to test and verify handling and emplacement procedures.

EARLY REPOSITORY EMPLACEMENT TESTS

The initial stage of the demonstration phase would involve early emplacement in the repository of the material packaged conservatively during the first generic packaging and handling tests. This would occur after NRC had granted a construction authorization but before completion of the first process line of the packaging facilities of the repository. Informal discussion with NRC staff indicates that this would be possible within the framework of the existing regulations for repository licensing; it would be analogous to low-power licensing for a reactor. As noted earlier, emplacement during this phase would use the conservative disposal system design. Early emplacement of a small amount of waste under licensed conditions would be a logical extension of the activities at a TEF if one were constructed at the repository site.

Such tests would offer a number of potential benefits. First, it would allow an early test of one of the crucial steps in the licensing process: NRC's ability to decide to allow actual "disposal" as defined by NWPA—permanent emplacement of waste in a geologic repository with no foreseeable intent of recovery. Second, because emplacement of even a small amount of waste with NRC approval would be disposal, it should satisfy the requirement in section 302(a)(5) that disposal in a repository begin by January 31, 1998. NWPA does not specify the level of operation that must begin by that time, but it does specify that emplacement be disposal, which presupposes NRC permission for permanent emplacement with no intent of recovery. Thus, this approach could allow disposal to begin perhaps several years earlier than 1998, assuming that the construction authorization for the first repository is granted on schedule.

TESTS OF REPOSITORY PACKAGING FACILITIES

A final stage of testing in the demonstration phase would be operation of the initial process line of the full-scale packaging facilities. For this stage, one processing line would be constructed and operated for a period of several years in order to discover and correct any design problems before constructing the rest of the process lines in the facility. While initial emplacement during the demonstration phase will use the conservative baseline design, the optimized system design would be demonstrated in this phase. Thus, the schedule for earliest operation in this phase depends on the time required to develop and gain NRC approval of an optimized design. Once the final designs have been modified as needed in light of this operational experience and the rest of the processing lines have been built, the RD&D program would be finished and the full operational phase would begin.

Integrated System Model

Evaluation and comparison of alternative waste management system designs with the conservative baseline design would greatly benefit from development of an integrated systems model that allows analysis of the total costs, risks, worker exposures, and other operational characteristics of waste management system designs from the time spent fuel is discharged from the reactor to the time of final disposal. As noted in the discussion of the integrated waste management system in chapter 3, many elements already exist which could be combined into an integrated model.

It is important to recognize that an optimum system design may involve elements that are not optimum if viewed from a narrower perspective. For example, from the point of view of the individual utility, using a multipurpose container for spent fuel might appear to increase interim storage costs, yet use of such containers may substantially reduce the total system costs. As another example, steps that could improve safety in one area could reduce it elsewhere; for example, while treatment of spent fuel to reduce its solubility may improve repository performance in the long run, it would lead to increased operational risks and generation of additional waste streams that must be disposed of.

An integrated system model is needed to capture all of these effects, so that decisions can be made on the basis of a clear understanding of the implications of the options under consideration. Another area in which integrated analysis is needed concerns the tradeoffs between distance between waste packages when emplaced in the repository, concentration of waste in the waste form and package, use of a corrosion-resistant waste package, and additional cooling prior to disposal.[59]

Alternative Disposal Technologies

Confidence that a permanent disposal system will ultimately be available could also be enhanced by the development of alternative disposal technologies. Such development is required by section 220 of NWPA.

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[59] National Research Council, *Isolation System*, p. 15.

A STRATEGY FOR REVISING THE MISSION PLAN

It is to be expected that future analysis and research will provide information that may allow relaxation of some of the convervatisms in the initial Mission Plan or significant changes in the system design. The initial Mission Plan should identify those points in the repository development process at which it is expected that sufficient new information would be available to warrant reexamination of the Plan. Alternatively, provision could be made for reassessment of the Mission Plan every 3 years, to provide a basis for the triennial budget and authorization process established by NWPA. Use of the Mission Plan for that purpose is discussed further in chapter 7.

The initial Mission Plan could also specify what steps would be taken to review and revise the Plan. Because the choices to be made in the Mission Plan have significant implications for many affected parties, public acceptance of and confidence in the Plan might be enhanced by broad involvement of the various affected parties in the proces of review and revision. (See discussion of the role of the Mission Plan in public participation in ch. 8.) This could also build consensus on the Plan, thereby reducing the likelihood of successful efforts to cause changes that favor one group or another or to thwart the Plan's implementation.

CHAPTER NOTE

Available analysis shows that there are strong financial incentives for use of cask or drywell storage at reactor sites—the same modular technologies that would also likely be used for a centralized storage facility designed to provide a limited amount of storage for a relatively short period. Thus, the main difference between at-reactor and centralized storage would be the difference in the cost of the packaging and handling facilities required in each case. DOE estimates that a cask storage facility with an annual receiving rate of about 2,000 tonnes would require handling and support facilities costing about $410 million.[60]

By 2008, the reactors that are now operating or under construction are expected to require about 2,300 tonnes per year of additional storage capacity beyond that available in their own basins (see app. E). About 1,500 tonnes per year of that amount would be from reactors that will have to provide their own storage facilities by 1998, so construction of new handling facilities for that fuel at a centralized site would duplicate costs that have already been incurred. The remaining 900 or so tonnes per year is from reactors that would not have to provide additional storage facilities until 1998 or later. This represents the annual discharge of about 30 1-Gwe reactors.

The estimated capital cost of facilities for lifetime cask storage for *two* such reactors at the same site is $7,100,000.[61] This in turn suggests that the total capital cost for the at-reactor facilities for 900 tonnes per year would be well under $200 million. Since these costs would be spread out over the 10-year period, the discounted cost would be less, compared to the discounted cost of a centralized system in which most of the capital costs are incurred at the beginning. While a detailed analysis will be required to provide an accurate comparison of at-reactor and away-from-reactor storage costs (an analysis that would benefit from completion and evaluation of the dry storage RD&D program mandated by NWPA), this rough estimate indicates that there is no strong prima facie reason for concluding that dry storage using modular systems will benefit from large economies of scale if implemented at centralized sites.

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[60] D. E. Rasmussen, *Comparison of Cask and Drywell Storage Concepts for a Monitored Retrievable Storage/Interim Storage System*, Battelle Memorial Institute Pacific Northwest Laboratory, PNL-4450, December 1982, table A.29, p. A.30.

[61] E. R. Johnson Associates, Inc., *A Preliminary Assessment of Alternative Dry Storage Methods for the Storage of Commercial Spent Nuclear Fuel*, JAI-180, DOE/ET/47929-1, Reston, Va., November 1981, table 8-2.

Chapter 7

Federal Institutional Issues

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Chapter 7

Federal Institutional Issues

The history of the Federal waste management effort strongly suggests that changes in past institutional arrangements and procedures may increase the credibility of the central component of the Nuclear Waste Policy Act of 1982 (NWPA)—the commitment to the development of a complex technological system, despite technical and institutional uncertainties, on a firm schedule extending over a period of decades. As discussed in chapter 4, there are three particular areas of concern regarding the capacity of the Federal Government to implement a waste management policy successfully: funding for the program, organization and management of the program, and coordination among the agencies that will be involved in waste management.

This chapter will discuss each of these concerns, the ways in which they have been addressed in NWPA, and some of the important questions that remain to be resolved.

PROGRAM FUNDING

The direct and indirect costs of waste management probably will be a small fraction (several percent) of the cost of nuclear-generated electricity.[1] For example, the Congressional Budget Office (CBO) calculated that even if the costs of the waste disposal program were 160 percent greater than currently anticipated, it would add only about 3 to 4 percent to consumer electricity bills.[2] However, the absolute sums required to develop an operating waste disposal system will be quite large (see table 7-1). According to Department of Energy (DOE) estimates, about $4 billion of research and development (R&D) will be required over the next 20 years to develop the capability to dispose of radioactive wastes in mined repositories.[3] The total cost of developing and operating two mined repositories, which would be sufficient to accommodate all of the high-level radioactive waste that will be generated by the reactors now operating or under construction, is expected to amount to about $20 billion in 1982 dollars.[4] Assuming an average of 3-percent inflation per year over the entire period of repository development and operation, and taking into account some (but not all) sources of cost uncertainty, DOE estimates that actual program outlays could range from $35 billion to $64 billion.[5] Thus, the credibility of any Federal commitment to a long-term waste management program will depend on confidence that these large sums will be available as needed over a period of decades.

NWPA provided for funding of the Federal radioactive waste management program through a mandatory fee of 1 mill (one-tenth of 1 cent) per kilowatt-hour (kWh) on nuclear-generated electricity. The revenues from this fee will be placed in a Nuclear Waste Fund in the Treasury of the United States, and can be used only for waste management activities specified in NWPA. This restriction on the use of the fund will be of particular importance during the first few decades of collection of the fee, when the fund will accumulate large surpluses that must be allowed to accrue interest so that sufficient money will be available in later years.

It has been Federal policy since 1970 that the costs of commercial radioactive waste disposal be borne by the generators of the waste.[6] However,

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[1] The discussion of costs draws heavily on a staff working paper prepared for OTA by the Congressional Budget Office: "Financing Nuclear Waste Disposal," May 1981.

[2] Congressional Budget Office, *Financing Radioactive Waste Disposal*, September 1982, p. 27.

[3] U.S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, S-0020, June 1983, table A-1, p. 42.

[4] Ibid., p. 2.

[5] Ibid.

[6] App. F, pt. 50, title 10, CFR, Nov. 14, 1970, requires that upon delivery of high-level radioactive waste to a Federal repository, the party delivering such waste would pay the Federal Government a charge designed to defray all costs of disposal and perpetual surveillance.

Table 7-1.—Reference Program Costs for Waste Disposal

Cost category	Program cost (in billions of 1983 dollars)	Percentage of total program cost
Two 72,000 metric ton capacity repositories[a]:		
Construction	3.5	23—17[b]
Operating[c]	4.0—6.9	26—34
Decommissioning	0.7	5—4[b]
Transporting spent nuclear fuel[d]	2.3—4.0	15—20
Site selection, evaluation, and licensing	1.3	8—6[b]
Test and evaluation facility	0.2	1
Technological development	1.5	10—8[b]
Administration[e]	1.8—2.2	12—11
Total	15.3—20.3	100

[a] These costs refer to two repositories built in a salt medium. The costs of building and operating two hard-rock repositories would be roughly 2 percent higher. All CBO analyses assume the development of salt repositories.

[b] Although the specific program cost remains the same under different growth patterns, its corresponding share of total program costs will differ.

[c] The total operating cost for the two repositories depends on the schedule of nuclear electricity generation. The annual operating cost for each repository is $48 million per thousand metric tons of spent fuel received.

[d] Total shipping costs also depends on the nuclear-growth forecast; the annual cost per thousand metric tons of spent nuclear fuel shipped is $28 million. A no-growth scenario assumes that only 82,000 metric tons will be disposed of at a cost of $2.3 billion; the $4.0 billion projection refers to the three growth forecasts used by CBO.

[e] Administrative costs include aid payments to State and local governments and to Indian tribes affected by repository development and fund management costs. Administrative costs continue until the second repository is decommissioned, and thus depend on the schedule of nuclear-electricity growth.

[f] The range of total cost estimates reflects the repository schedules under the different nuclear-growth forecasts used by CBO.

SOURCE: Congressional Budget Office, *Nuclear Waste Disposal: Achieving Adequate Financing*, August 1984. Based on cost projections from Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020, June 1983.

it had been assumed, before passage of NWPA, that most of the costs of developing the disposal system prior to operation of the first repository would have to come from Federal appropriations, to be repaid when utilities delivered the waste to a Federal facility for storage or disposal.[7] If this repayment approach had been continued, progress in the waste disposal program for the next decade or two would have been dependent on competition for general revenues in the annual Federal budget process and thereby vulnerable to pressures to defer major expenditures (e.g., site evaluation activities) when the Federal budget was tight. Moreover, the period of dependence on Federal appropriations would have been uncertain, since offsetting revenues would have been determined by the utilities' independent decisions about when to deliver waste to the Federal Government.

Under the pay-as-you-go system established by NWPA, the utilities with nuclear reactors provide the front-end funding for the development of repositories. This method has the potential for assuring the availability of an adequate source of revenue, so that lack of resources can be eliminated as a limitation on the scope and timing of the technical waste management program.[8] This could allay any concerns that budgetary pressures might lead to "corner-cutting" that could compromise safety. It could also increase greatly the credibility of any waste management policy commitments of the Federal Government. In fact, OTA's analysis indicates that this funding arrangement may be necessary for a credible commitment to a firm schedule for developing and operating waste repositories.

To realize the full potential of a mandatory fee, two requirements must be met. First, there must be a means of adjusting the revenues from the fee to ensure that the full costs of the program are recovered despite inflation and unanticipated changes in program scope. Second, the revenues must be available for expenditure as needed. The first requirement will be considered in the remainder of this section; the second will be analyzed in the discussion of fiscal oversight mechanisms that follows.

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[7] See, for example, U.S. Department of Energy, "Preliminary Estimates of the Charge for Spent-Fuel Storage and Disposal Services," DOE/ET-0055, July 1978.

[8] Funding limitations have restricted the scope of the Federal site evaluation program in the past. See app. A, p. 213.

DOE has analyzed the revenues expected to be generated by the 1-mill/kWh fee established by NWPA and concluded that those revenues, including interest earnings when the fund is in surplus, should be just sufficient to cover total program costs for development and lifetime operation of two repositories, if there are no significant cost increases over current estimates other than an average inflation of 3 percent per year.[9] However, it should be noted that this conclusion is based on a repository development program that is little modified from the program that was in place before the enactment of NWPA, which for the first time established in law a firm Federal commitment to a specific date for repository operation. As discussed in chapter 6, the repository siting and development program needed to give high confidence that such a commitment can be met despite technical problems is likely to be more extensive and expensive than the program planned prior to passage of the Act.

If the mandatory fee is to provide sufficient revenues to enable the Federal Government to meet its waste management policy commitments, then it may be necessary to adjust the initial 1-mill/kWh level to cover the program needed to fulfill those commitments. (Historically, the program, and thus the achievable goals, have been determined to a considerable extent by the availability of appropriated funds.) Since the program expenditures to be covered by the fee will extend over a period of four or more decades, a plan of activities and their associated costs over an extended period will be needed. The long-term cost analysis required in the Mission Plan could be particularly useful as a basis for determining whether adjustments of the fee are needed.

Whatever the initial estimates of the long-term costs of the waste management program, the potential for unanticipated cost increases is very high.[10] There are many sources of cost uncertainty.[11] First, future inflation may be incorrectly estimated. For example, DOE's analysis shows that if average annual inflation is 5 percent instead of the anticipated 3 percent, it would increase aggregate program expenditures (in current dollars) by about $34 billion.[12] Second, current estimates are based on generic repositories, while the actual site-specific costs are likely to be different. Third, regulatory requirements for the disposal program are not final. Finally, there may be unanticipated technical problems that lead to increased costs. Both DOE and CBO agree that cost uncertainty is the principal source of financial risk to the disposal program.[13] Figure 7-1 shows a DOE estimate of the range of possible cumulative waste management costs.

Because the future costs of waste management are uncertain, there is a risk that the fee established by NWPA may not generate sufficient revenue to cover the actual costs of the program. Providing a mechanism for revising the fee to adjust for cost increases is important, not only if it is desired that all costs of the waste management program be borne by the generators of the waste, but also if it is desired to make credible long-term commitments for the development and operation of a Federal waste disposal system. If adjustment is difficult or impossible, then the revenues generated by the fee could, over the course of time, become inadequate to finance the program. In that event, history suggests that, once again, budgetary pressures might lead to program cuts (particularly in the number of backup sites and component technologies under parallel development) that could reduce the credibility of the long-term commitments. At the same time, if adjustments are too easy, there will be a risk that incentives for cost control would be weak.

NWPA deals with this by requiring the Secretary of Energy to review the adequacy of the fee annually and to propose any changes required to ensure that the full costs of the waste management program are recovered. It also provides for congressional control over such fee increases by specifying that either House can block a proposed in-

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[9] U.S. Department of Energy, *Report on Financing the Disposal*, p. 31.

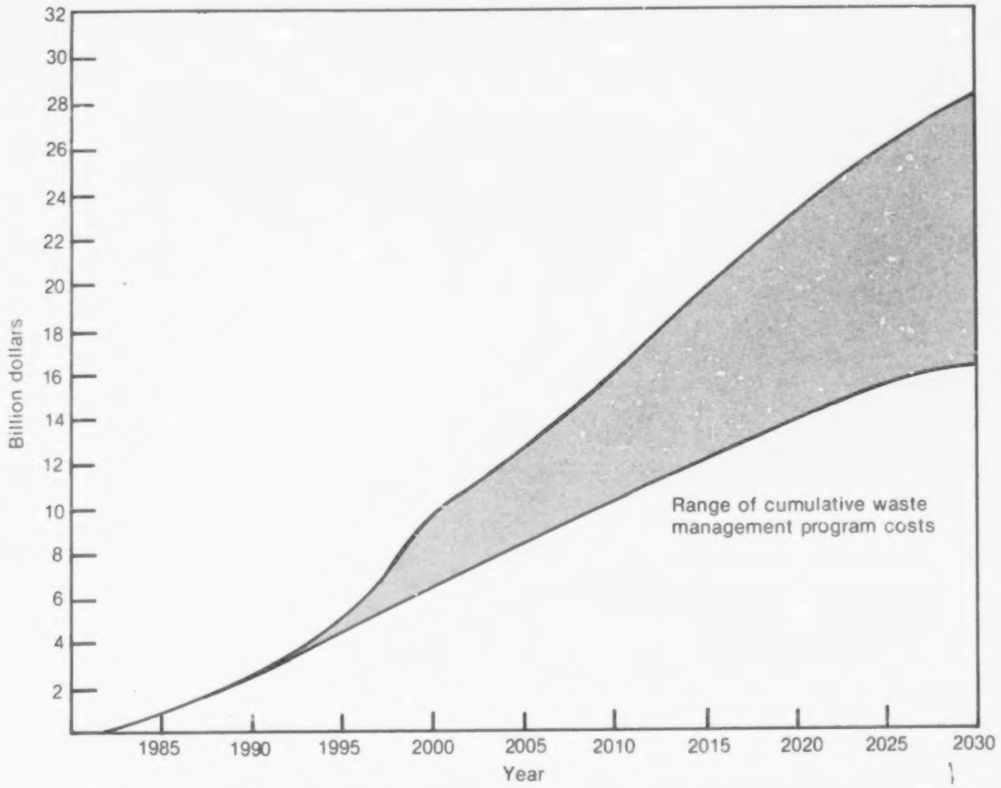
[10] Ibid., p. 3.

[11] See U.S. Department of Energy, *Report on Financing the Disposal*, and Congressional Budget Office, *Financing Radioactive Waste Disposal*, for analyses of sources and implications of cost increases.

[12] U.S. Department of Energy, *Report on Financing the Disposal*, p. 31. A recent Congressional Budget Office study concludes that the 1 mill fee will be inadequate if inflation exceeds 3 percent annually. Congressional Budget Office, *Nuclear Waste Disposal: Achieving Adequate Financing*, August 1984.

[13] U.S. Department of Energy, *Report on Financing the Disposal*, p. 32; and Congressional Budget Office, *Financing Radioactive Waste Disposal*, p. 24.

Figure 7-1.—Range of Cumulative Estimated Waste Management Program Costs (constant 1982 dollars)



SOURCE: U.S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020, June 1983.

crease. However, the Supreme Court's finding that such one-House veto provisions are unconstitutional[14] raises questions about the long-term effectiveness of the provisions for congressional review of adjustments of the fee. The problem of striking an appropriate balance between cost control and adequacy of revenues in light of the uncertainties resulting from the Supreme Court's decision will be considered below in the discussion of fiscal control mechanisms for the waste management organization.[15]

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[14] *Immigration and Naturalization Service* v. *Chadha et al.*, 103 S.C., p. 2764, No. 80-1832.

[15] See also U.S. Department of Energy, *Report on Financing the Disposal*, p. 32; and Congressional Budget Office, *Financing Radioactive Waste Disposal*, p. 32.

ORGANIZATION OF THE FEDERAL WASTE MANAGEMENT AGENCY

The implementation of the repository development program mandated by NWPA entails two major sets of requirements for the organization with primary responsibility. On the technical side, steady progress must be made through a series of R&D milestones to the goal of the operation of one or more full-scale disposal facilities. Such progress requires the ability to assemble and manage considerable financial and human resources over a period of decades, to ensure that resources remain at an adequate level to continue activities, and to coordinate technically diverse and demanding tasks.

The lead agency must also be attentive to nontechnical demands. Agency officials must be able to deal with a variety of non-Federal parties with conflicting viewpoints who have the power to delay waste management efforts if they are dissatisfied. In such a situation, the ability to negotiate and bargain is important, as is the ability to forecast demands of non-Federal parties and the possible effects of such demands on the waste management program.

Radioactive waste management has suffered in the past from problems in policy and program planning, in the coordination of agency activities, and in responsiveness to the expressed concerns of groups affected by waste management, such as utilities, environmentalists, and State officials (see ch. 4). These and other problems have led to suggestions that there be changes in the agency with principal responsibility for radioactive waste management, currently DOE. The suggested changes fall into two broad categories: those related to the position of the waste management program within the Federal Government, and those related to the internal organization of the program.

At the time NWPA was being debated, alternatives to the existing institutional structure for waste management had been studied less thoroughly than the technical options. It was felt unnecessary and premature to attempt to make major institutional changes at that point before a long-term technical program had been adopted. Instead, Congress chose at that time to correct some of the most obvious institutional problems by establishing within DOE the Office of Civilian Radioactive Waste Management, with a Director appointed by the President and reporting to the Secretary of DOE, and to leave the question of more basic structural changes for later consideration. To ensure that institutional questions would be addressed in more detail in the future, NWPA also requires DOE to submit to Congress a report on alternative institutional approaches to managing the radioactive waste program, including the option of establishing a private corporation. Each of these steps will be discussed further below.

The Office of Civilian Radioactive Waste Management

Historically, the principal Federal responsibility for radioactive waste management has been discharged by a program office located within an organization having many broader responsibilities concerning nuclear power—initially the Atomic Energy Commission, then the Energy Research and Development Administration, and now DOE.[16] As a result, the Federal waste management program has had to compete for money, manpower, and policy-level attention with more popular or urgent areas of nuclear R&D.

Establishment of the waste management program as a single-purpose office that is independent of other nuclear activities of DOE should stabilize the waste management organization at an appropriate policy level, insulate it from competition with other nuclear policy areas, and make possible the central integrated planning and management needed for ensuring implementation of a long-term waste management policy.[17] This should also insulate the waste management organization from any major institutional uncertainty or delay that could occur if the Federal energy activities were reorganized, as has been proposed by the Reagan administration.

While NWPA moved the location of the waste management office within DOE, some changes within the office itself may be desirable. The Office of Civilian Radioactive Waste Management is based on the waste management organization in DOE that existed prior to passage of the Act. The ability of that organization to implement a radioactive waste policy has been questioned by some observers.[18] The history of the waste management program suggests that some changes in internal organizational structure may help build confidence that the commitment in NWPA to operate a repository by 1998 can be met.[19] Such changes may be useful regardless of whether there is any shift in the organizational location of the waste management program. The following discussion will briefly consider some of the principal types of changes that have been suggested.

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[16] For a discussion of the evolution of the waste management organization, see app. A.

[17] See, for example, National Academy of Public Administration, "Building the Institutional Capacity for Managing Commercial High-Level Radioactive Waste," May 1982, p. 4.

[18] See Irvin C. Bupp, "The Management of the National Research and Development Program," statement prepared for the California Energy Commission, May 30, 1980, p. 4.

Some observers, particularly some State officials, have questioned DOE's planning and implementation abilities in nontechnical areas of waste management (e.g., dealing with sociopolitical impacts) that may be as important as the technical areas for successful siting and development of a repository.[20] Though proficient in technical areas, some DOE personnel are seen as lacking the nontechnical skills and sensitivities important for planning for relations between DOE and non-Federal participants.[21] Yet NWPA contains many requirements for extensive DOE relations with States and the public. While there appears to be growing appreciation at DOE of the importance of nontechnical questions in implementing a radioactive waste program, no single office or manager has been clearly responsible for dealing with them. As a result, even though contractors to DOE have produced many studies in nontechnical areas, there is no clear mechanism for transferring the results of their analysis into policy and programs.[22] Implementation of NWPA might be facilitated if responsibility for dealing with such nontechnical aspects of the waste program were explicitly assigned to a staff group with the expertise needed to deal with them. This may require the addition of staff with the appropriate skills and experience.[23] In response to such concerns, the Office of Civilian Radioactive Waste Management has recently established an outreach division (see fig. 7-2).

Changes may also be needed to strengthen DOE's ability to plan and coordinate the many activities that will be involved in developing and deploying an operating repository system on schedule. As discussed in chapter 5, OTA has concluded that one of the basic requirements for making a commitment to a firm repository schedule credible is the development of a sound implementation plan, showing precisely how the Federal Government proposes to meet the schedule. NWPA includes a requirement for development by DOE of a comprehensive Mission Plan. However, historically the DOE waste program has lacked the strong central planning and analysis capacity that would be required to develop an integrated Mission Plan. Instead, it has relied on a relatively small central staff to coordinate the activities of field offices and contractors.[24] That central staff has been divided along functional lines (e.g., spent fuel storage and repository development), with little or no emphasis placed on analysis of how all the individual functions could be integrated into a comprehensive waste management system.

Passage of NWPA, which mandates both a schedule for repository operation and a wide range of technical and nontechnical activities prior to operation, places an even greater demand on the waste management organization to ensure that those activities are coordinated most effectively if the schedule is to be achieved. Unless there is sub-

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[19] For an analysis of the institutional problems in implementing a radioactive waste management program, see Jackie L. Burns, "Institutional Issues in the Planning and Implementation of a Program to Dispose of High-Level Radioactive Wastes," Rand Corp., N-1650-DOE, 1981. See also National Academy of Public Administration, op. cit., pp. 40-42.

[20] This was apparent in many interviews with State officials conducted by OTA staff and contractors. This view was also expressed, for example, by the South Carolina Governor's Task Force on Advanced Nuclear Systems, which concluded that lack of proper attention to, and planning for, socioeconomic and sociopolitical impacts had been a major impediment to implementation of waste management and disposal systems. "Review of—'Draft Report of Department of Energy Task Force for Review of Nuclear Waste Management,' " June 1, 1978, p. II-7.

[21] See Pat Choate and John Bowman, "Radioactive Waste Management: State Concerns," a report to OTA from the Academy for Contemporary Problems, 1981.

[22] For a comprehensive discussion of these and other management problems, see Burns, op. cit.

[23] Ibid., p. 87.

[24] Some have noted that this management structure also affects DOE's ability to deal with nontechnical requirements. For example, the Summary Report of the Second Keystone Conference on Public Participation in Radioactive Waste Management Decisionmaking stated that, "A major barrier to establishing an effective public participation program at DOE is the lack of overall management capability at headquarters. It is perceived that most of the people at DOE headquarters are contract officers and not program managers. Concern was expressed that no one was paying sufficient attention to the absence of a strong program management capability at DOE, in comparison to the disbursement of funds overwhelmingly to contractors." "Public Participation in Developing National Plans for Radioactive Waste Management" (Keystone, Colo.: The Keystone Center, October 1980), p. 15.

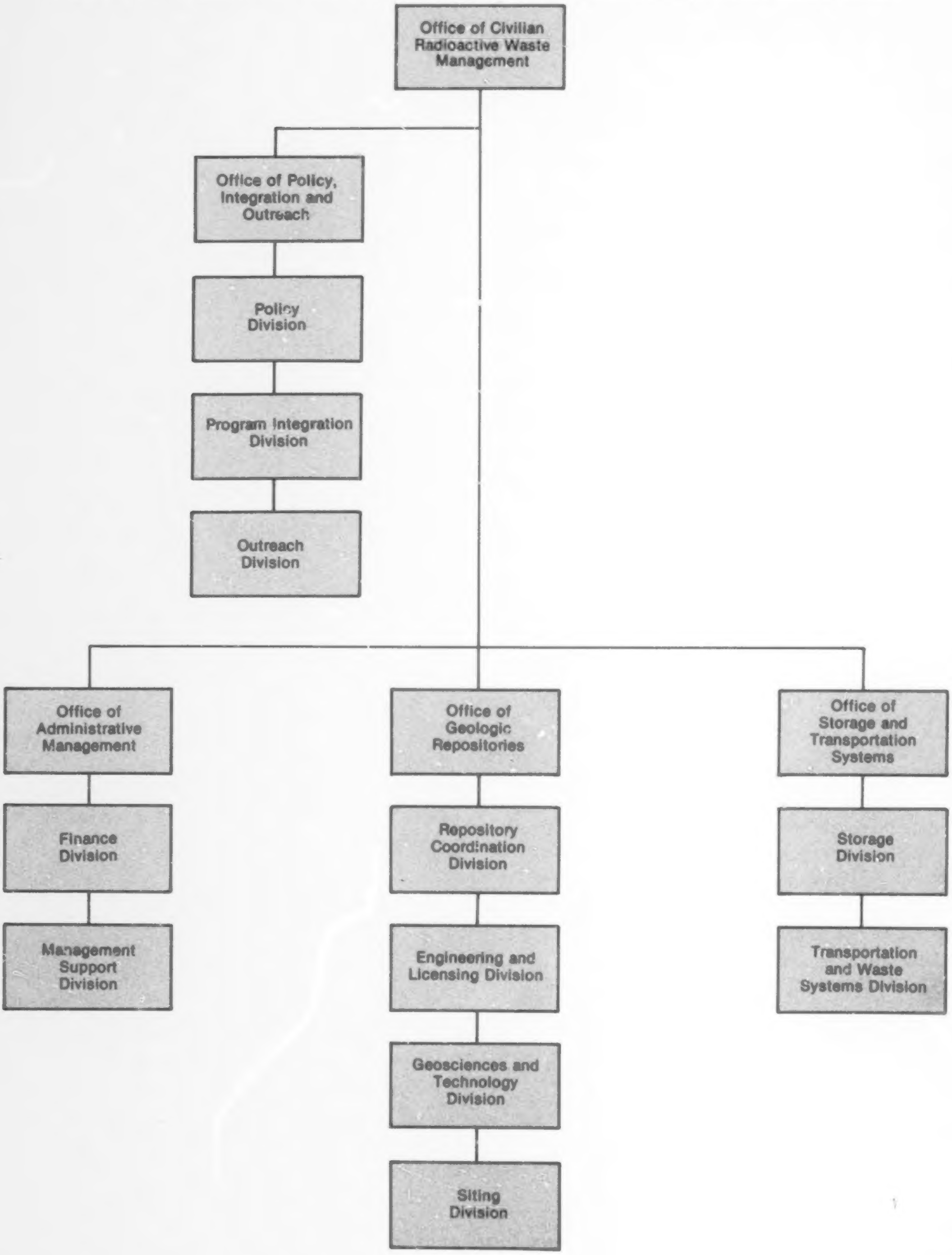

Figure 7-2.—Organization Chart of the Office of Civilian Radioactive Waste Management

Office of Civilian Radioactive Waste Management
Office of Policy, Integration and Outreach
Policy Division
Program Integration Division
Outreach Division
Office of Administrative Management
Finance Division
Management Support Division
Office of Geologic Repositories
Repository Coordination Division
Engineering and Licensing Division
Geosciences and Technology Division
Siting Division
Office of Storage and Transportation Systems
Storage Division
Transportation and Waste Systems Division

stantial direct involvement by DOE program staff in the development of the Mission Plan, it may have little chance of achieving its potential as a key management tool for coordinating the many activities required to meet the goals of NWPA. This may require establishment of an adequately staffed and funded group within the waste management office with responsibility for integrated systems analysis and mission planning. In response to these concerns, the Office of Civilian Radioactive Waste Management recently established a program integration division.

Implementation of NWPA may also require strengthening of the capacity of the DOE central office program staff to manage the field activities of the program. Historically, radioactive waste management functions have been handled by geographically separate organizational units that operate different programs and laboratories.[25] Because field offices have latitude in program implementation, including relations with States in the course of siting activities, coordination is more difficult to maintain. Yet, NWPA's commitment to a firm schedule for operation of a repository may make such coordination even more important than it has been in the past.[26]

Alternative Means of Financing and Management

In addition to establishing an Office of Civilian Radioactive Waste Management within DOE, NWPA also requires the Secretary of Energy to study and report to Congress on alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities.[27] The study is to consider the feasibility of establishing an independent, single-purpose waste management organization, including a private corporation.

OTA's analysis of the history of the Federal radioactive waste management program concludes that the credibility of NWPA's commitment to the development of a complex technological system on a firm schedule could be enhanced by the establishment of an independent waste management agency with more funding and management flexibility than is usual with a typical Federal program. This section will discuss some of the arguments for creating an independent organization and will focus on the problem of providing adequate oversight and control over such an organization.

At present, DOE is responsible for numerous policy areas in nuclear energy besides radioactive waste management and for a host of other energy-related programs. Units in DOE responsible for waste management have in the past had to compete with other units for funding and staff. Given the long time span during which development of the waste management system will take place, waste management could receive inadequate attention relative to other functions, both from outside policymakers and from DOE itself, if it continued to be treated simply as one program among the many for which DOE is responsible. Moreover, what was seen by the Interagency Review Group (IRG) as a strength of DOE—its ability to maintain an appropriate perspective on waste management in relation to energy production—may, in some senses, be a liability.[28] Some groups fear that DOE's mission as a promoter of energy production could conflict with the safe planning and development of a radioactive waste management system. A separate radioactive waste management authority could be insulated from promotion of nuclear power in a way that DOE would find difficult to match.

Creation of a new organization with a narrow, mission-oriented focus on radioactive waste management would greatly reduce the chance that organizational resources would be diverted to other, competing missions. The attention of outside policymakers to waste management issues might be increased through the increased visibility such an organization would give to radioactive waste management and by the reduction of internal organizational layers that now exist at DOE. Finally, to outside parties, change can signal a fresh start and a break with existing practice.

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[25] See, for example, Roger Kasperson, "Institutional and Social Uncertainties in the Timely Management of Radioactive Wastes," testimony prepared for the California Energy Commission, June 30, 1980, pp. 11-16. See also Burns, op. cit.

[26] President Kennedy's commitment to land a man on the Moon by the end of the 1960's required new organizational modes at the National Aeronautics and Space Administration. In particular, a much stronger headquarters team was needed to coordinate the efforts of several research centers that would be involved. See Frank W. Anderson, Jr., *Orders of Magnitude: A History of NACA and NASA, 1915-1976* (Washington, D.C.: National Aeronautics and Space Administration, 1976), p. 31.

[27] To conduct this study the Secretary of Energy appointed an advisory group formally titled the Advisory Panel on Alternative Means of Financing and Managing Radioactive Waste Facilities. The first meeting was held in January 1984, and the report of the panel was delivered to the Secretary at the end of 1984.

[28] *Report to the President by the Interagency Review Group on Nuclear Waste Management*, TID-29442, March 1979, p. 117.

Establishing a separate organization could leave open later options for organizational change—e.g., the transfer of responsibility for operating storage or disposal facilities to the private sector—to a greater extent than would occur if responsibility for the Federal waste management program remained with a program unit within DOE. If a corporation were later created to manage the entire nuclear fuel cycle, as proposed by some, an independent agency might more easily merge with such a corporation than could a program within DOE. Similarly, creation of an independent radioactive waste management agency may be most compatible with a later decision to create a broader Federal hazardous waste management authority dealing with both radioactive and nonradioactive toxic wastes in general.[29]

There are many possible models for a separate radioactive waste management authority, including a federally chartered public corporation, such as the Tennessee Valley Authority (TVA); an independent authority with loose ties to DOE, such as the Bonneville Power Administration; or a new agency in the executive branch. Some analyses of the nature of radioactive waste management responsibilities have suggested that a corporate structure may be most desirable for a waste management organization.[30] For example, corporate structure is most consistent with the self-financing nature of a program funded entirely through user fees, and with the high degree of discretion over annual expenditures from a trust or revolving fund needed to give confidence that a long-term schedule can be met. (Since the organization would be self-financed through the waste management fee, any additional costs involved in establishing and operating a new, single-purpose agency would be borne by the users of nuclear power rather than by the Federal taxpayer.) A definitive conclusion concerning the most suitable organizational form would require a more extensive investigation of the advantages and disadvantages of the various possible models than OTA was able to perform.[31]

A major question to be addressed in the organizational study of alternative structures for the lead waste management agency is the degree of independence the agency would be granted in the performance of assigned responsibilities, especially in discretion over annual expenditures. Government corporations, for example, normally have more independence than Federal agencies.[32]

Greater independence makes organizations more resistant to political fluctuations and enables greater flexibility in hiring and firing and in rewarding good performance and penalizing nonperformance. If the organization has control over use of its revenues, uncertainties of the annual appropriations process can be avoided.[33]

On the other hand, greater independence could prove detrimental if oversight were insufficient to allow adequate responsiveness to interests and concerns of groups outside the organization. In some instances, insulation from outside political influence has led managers of government corporations to overemphasize financial criteria, an action that could be fatal to the credibility of a radioactive waste management organization.[34] Thus, a particularly important question in establishing a more independent waste management authority will be how to ensure a satisfactory degree of congressional oversight and public accountability.

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[29] Efforts to site facilities for treatment and disposal of toxic wastes encounter many of the same difficulties associated with siting radioactive waste management facilities, and some of the technical problems of providing isolation with an acceptable level of confidence are similar. Thus, it could be argued that there would be advantages to a single hazardous waste management agency. Along these lines, the U.S. Geological Survey has created a single Office of Hazardous Waste Hydrology that deals with both radioactive and nonradioactive waste issues.

[30] See Mason Willrich and Richard Lester, *Radioactive Waste: Management and Regulation* (New York: The Free Press, 1977).

[31] A preliminary analysis of organizational issues is found in *An Organizational Analysis of a Nuclear Waste Management System* by Randall F. Smith, report prepared for the Office of Technology Assessment by Battelle Human Affairs Research Centers, BHARC-311/80/010, March 1980. See also National Academy of Public Administration, op. cit., pp. 40-42; and Jackie L. Braitman, *Nuclear Waste Disposal: Can Government Cope?* (Santa Monica, Ca.: The Rand Graduate Institute, December 1983).

[32] National Academy of Public Administration, "Report on Government Corporations," vol. 1, August 1981; see also Harold Seidman, *Politics, Position, and Power*, 3d ed. (New York: Oxford University Press, 1980), pp. 265-276.

[33] A survey of utilities' attitudes about the Federal waste management program showed a desire that funding for radioactive waste management be independent of problems in the Federal budget and DOE budget cycles. See "Developing a Federal Policy on Spent Nuclear Fuel," Task 2 Draft Report, prepared for DOE, Assistant Secretary for Policy and Evaluation, Office of Coal and Electrical Systems Policy, by Resource Planning Associates, Inc., and International Energy Associates Ltd., June 1978.

[34] Annmarie Hauck Walsh, *The Public's Business: The Politics and Practices of Government Corporations* (Cambridge, Mass.: MIT Press, 1978), p. 6.

Because of concerns about the responsiveness of past Federal waste management efforts, there may be considerable reluctance to establish a lead organization with any greater independence than DOE for fear that it might be less responsive to the concerns of Congress, the administration, and the public. Achieving an acceptable balance between independence and accountability will therefore be one of the central challenges in designing an independent waste management authority. The following discussion considers possible means of achieving such a balance through the general oversight structure for the waste management agency and through fiscal control mechanisms.

Oversight Structure

The oversight structure of an independent waste management agency could be similar to that of a public utility, since the agency would have a monopoly on disposal of commercial waste and utilities would be required to use its services. Supervision of the management of the agency could be exercised by a board of directors, appointed by the Secretary of Energy, Congress, or the President, with possible congressional confirmation of appointments. Such a board could include members from Congress, DOE, and other Federal bodies, as well as from non-Federal groups such as State and local governments, utilities, public service commissions, and environmental organizations. Alternatively, such non-Federal groups could be represented through a public advisory commission established as part of an oversight structure.[35]

Fiscal Control

Whatever formal oversight structure is chosen, control of the finances of the waste management agency will be of particular concern. There are two distinct aspects of fiscal control that should be addressed in an analysis of institutional alternatives: control over the level of the mandatory waste management fee established by NWPA, and control over the agency's expenditures from the Nuclear Waste Fund.

CONTROL OF REVISIONS OF THE FEE

The discussion of program funding indicated the importance of providing some mechanism for adjusting the waste management fee to cover unanticipated costs. Because of the importance of the fee adjustment mechanism to the success of the waste management program, and the uncertainty created by the Supreme Court's decision concerning the one-House veto, which raised questions about the provisions in NWPA for congressional control of revisions of the fee, it would be useful for any congressional deliberations on alternative institutional arrangements to consider alternative fee adjustment mechanisms.

Two possibilities are: 1) complete delegation of authority to revise the fee to the head of the waste management agency, with no provisions for congressional review; and 2) revision of the fee only through amendment of the 1-mill/kWh level established by the Act. In either case, it may be difficult to strike a balance between the oversight needed to ensure efficient use of the revenues from the fee and the assurance that revenues will be sufficient to cover all of the costs of the program needed to provide confidence that the commitments in NWPA can be met.

If the head of the waste management agency were given the authority to adjust the fee, and Congress' only means of vetoing such an adjustment were through specific legislation, direct congressional control would be difficult—both because of the inherent complexity of the legislative process and because such legislation would have to be signed by the President, who might be inclined to support the action of the head of an executive branch agency.

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[35] The July 1978 Radioactive Waste Management Discussion Group sponsored by the Keystone Center for Continuing Education recommended the creation of a Public Advisory Committee, with members from citizens' groups, private industry, universities, local and State governments, and Congress, to ensure "effective two-way communication between the federal government and concerned segments of the public, thereby improving the federal program and developing a broader understanding of that program outside of the federal government." Letter to Frank Press and John M. Deutch, Sept. 9, 1978, p. 8.

Adjustment of the fee in this case might be too easy, thereby weakening the incentives for efficiency and good management.

If there were no specific provision dealing with adjustment of the fee, then the 1-mill/kWh fee could only be changed by amendment of NWPA itself. In this case, adjustment of the fee would be quite difficult, in part because of the general difficulty of the legislative process and in part because of reluctance to amend the Act. As noted earlier, if it is too difficult to adjust the fee to cover unexpected cost increases, the result may simply be that the scope of the waste management program is reduced to match the available revenues. This would eventually lead to a situation in which progress in repository development becomes limited by the availability of resources, which would not be fully compatible with NWPA's firm commitment to a schedule for repository operation.

One possible adjustment mechanism that has been suggested is automatic adjustment of the fee according to an index of inflation (see table 7-2).[36] Another possibility for revising the fee is suggested by the fact that an independent waste management agency would, in effect, be a public utility with a mandatory fee on its users. Thus, it might be possible to have an independent body, analogous to the Postal Rate Commission, review and perhaps even approve proposed fee revisions.

If more direct congressional control were desired, the mechanism of a joint resolution, as provided in NWPA for dealing with a State's objection to a repository site (see ch. 8), might be used. If a joint resolution were required to veto a proposed fee revision, the degree of congressional control over changes of the fee would be limited by the ability of the President to veto the resolution.[37] On the other hand, it would reduce the likelihood that needed fee increases would be deferred simply because of congressional inaction. If enactment of a joint resolution were required to approve a proposed fee revision, the degree of congressional control would be substantially higher, although it might increase the chance that needed revisions would be deferred.[38]

Table 7-2.—Nuclear Waste Fund Projections Under the DOE Reference Program Schedule (in billions of 1983 dollars)

	High nuclear growth	Medium nuclear growth	Low nuclear growth	No nuclear growth
Fixed fee of 1 mill per kilowatt-hour:				
Total program costs	20.0	20.1	20.3	15.3
Total fee collections[a]	16.2	15.4	14.2	10.7
Net interest[b]	3.2	1.3	-2.4	-1.2
Final fund balance	-0.6	-3.4	-8.5	-5.8
Optimal fee for zero final balance (in mills per kilowatt-hour)	1.02	1.10	1.19	1.22
Fee increased by annual inflation rate[c]:				
Total program costs	20.0	20.1	20.3	15.3
Total fee collections[b]	34.8	34.2	34.3	17.7
Net interest[b]	27.1	26.1	31.0	10.5
Final fund balance	41.9	40.2	45.0	12.9
Optimal fee for zero final balance (in mills per kilowatt-hour)	0.50	0.52	0.55	0.72

NOTES: The long-term inflation and real interest rate assumptions are 4.3 percent and 3.5 percent, respectively.

[a] Total fee collections include the one-time payments made for spent fuel generated before April 7, 1983, estimated at $2.3 billion (in nominal dollars).

[b] Net interest includes earnings on invested fund revenues and payments on borrowed funds.

[c] This fee design would increase the current fee by the annual percent change in the gross national product price deflator, beginning in 1984. The optimal fee under this schedule refers to the rate the fee should have been set at in 1983 in order to leave a final fund balance of zero.

SOURCE: Congressional Budget Office, *Nuclear Waste Disposal: Achieving Adequate Financing*, August 1984.

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[36] H.R. 4690, introduced in the second session of the 98th Congress, would amend the fee adjustment provisions of NWPA to require automatic correction of the fee to keep up with inflation, following NRC approval of a construction authorization for the first repository. This approach is analyzed by the Congressional Budget Office in *Nuclear Waste Disposal: Achieving Adequate Financing*.

[37] S. 1650, introduced in the first session of the 98th Congress following the Supreme Court's decision on the one-House veto, would provide for congressional veto of agency actions through passage of a joint resolution, which would have to be signed by the President.

[38] H.R. 4690 would also allow the Secretary to propose fee changes in addition to the automatic adjustments for inflation, but those changes must be approved by Congress through passage of a joint resolution.

CONTROL OF EXPENDITURES FROM THE NUCLEAR WASTE FUND

Assurance of steady progress in development of a waste management system requires assurance that adequate funds will be available as needed. This in turn requires not only assurance of sufficient revenues but also assurance that the revenues will be made available to the waste management agency as needed to carry out the program. In this regard, NWPA makes expenditures from the Nuclear Waste Fund subject to annual appropriations. This provides a high degree of congressional control over program financing, which may be seen as particularly desirable if the head of the waste management agency is given power to revise the fee. On the other hand, it also raises questions about whether sufficient funds will be available each year to carry out a long-term repository development program on schedule. For example, there may be pressures in the appropriations process to defer large capital expenditures in years in which the Federal budget is particularly tight. This may be inconsistent with the assurance of predictable annual funding needed to ensure that a firm, long-term schedule can be met. Thus, there appears to be an inherent conflict between a stable commitment to a fixed schedule for a complex technical project and a high degree of external budgetary control.

There is a wide range of alternatives for congressional control over the finances of a Federal entity. At one end of the spectrum in terms of independence is TVA, which has direct control over the use of the funds generated by the sale of electricity, although its budget is shown as part of the Federal budget. Congressional influence is exercised through annual oversight of TVA activities, direct control of its debt ceiling, and appointment and confirmation of its board of directors.

An alternative that lies between the financial independence of TVA and annual appropriations control would be to provide for multiyear appropriations, which might be justified in view of the long-term nature of the repository development program and the need for adequate and predictable funds over an extended period of time. NWPA takes a step in this direction by providing that the budget for the Nuclear Waste Fund is to be submitted, and the appropriations from the fund are to be authorized, on a triennial basis.

Role of the Mission Plan in Agency Oversight

To exercise fiscal control over the waste management program, the responsible oversight authorities need justification of proposed revenues generated by the fee and expenditures from the fund. The Mission Plan required by NWPA might be particularly well suited for this purpose, if it contained a detailed, long-term budget for the expenditures and revenues required to implement the Plan. In fact, *the Mission Plan could serve as the principal mechanism for balancing the need for adequate congressional oversight with the need for increased flexibility of operation and funding.*

DOE analysis shows that the cost of waste disposal will mainly be determined by the scope of the repository R&D program, the timing of construction and operation of full-scale disposal facilities, and the design of the repository. Therefore, to ensure that the fee to be charged to utilities to finance the waste management program covers all of the costs required to meet the legislated objectives, the fee must be based on a clearly defined plan for developing and operating a repository system. The Mission Plan could provide such a basis for the fee, and for appropriations from the Nuclear Waste Fund.

To be most useful as a basis for fiscal control, the Mission Plan would have to be revised periodically to take into account the fiscal effects of inflation, unanticipated difficulties, program changes required by new information, or other developments. For example, congressional consideration of a proposed fee revision might be facilitated if the proposal were accompanied by a revised version of the Mission Plan that clearly justifies the change in the fee in terms of such factors. Congressional review of a budget for multiyear authorizations or appropriations could similarly benefit from provision of a revised Mission Plan that gives a detailed analytical basis for the budget. The amount of time required for congressional review of fiscal matters could be reduced if proposed fee revisions were submitted at the same time as multiyear budgets, and if proposed revenues and expenditures were justified by a single revised Mission Plan document.

NWPA does not require revisions of the Mission Plan after it has been submitted to Congress, nor does it explicitly link the Mission Plan to the determination of revisions of the fee or to the triennial budget authorization and annual appropriations process. However, NWPA does require that the Mission Plan contain an estimate of the annual expenditures needed to carry out its objectives, and NWPA does not appear to preclude DOE from revising the Plan as necessary for use as a justification for fee changes and appropriations from the fund.

Use of the Mission Plan as a basis for oversight and accountability of an independent waste management agency could be strengthened by creation of a process for congressional approval of the Mission Plan. OTA's analysis of the history of Federal waste management efforts suggests that it may be unlikely that broad agreement can be reached on establishing an independent waste management agency unless there is explicit agreement about what the agency is going to do and how it is going to do it. Congressional approval of a Mission Plan for implementing the goals enacted in NWPA would establish such an agreement. Thus, the function of the waste management agency would not be to develop broad waste management policy, but rather to carry out a specific program to implement specific goals, a program Congress has formally approved. Once approved, the Mission Plan could serve as the main yardstick by which Congress—and a board of directors or any other body, including the public--could oversee the activities and expenditures of the waste management agency and measure its progress.

A process of extensive public and technical review of the draft Mission Plan prior to congressional approval could help develop broad national understanding and agreement on waste management policy. This agreement, combined with explicit congressional approval, could enhance the credibility and stability of the program.[39]

There are many possible options for providing some form of congressional approval of the Mission Plan. These range from direct approval through an explicit joint resolution procedure, such as that included in the Synfuels Act for congressional approval of a national synfuels strategy, to indirect approval through approval of authorizations, appropriations, or fee revisions explicitly based on the Mission Plan.

In developing procedures for congressional approval of the Mission Plan as part of the oversight mechanism, several considerations should be taken into account. First, the elements of the Mission Plan subject to congressional review and approval should not be too detailed. For example, it may be appropriate for Congress to approve a long-term schedule of activities and associated expenditures and revenues derived from a more detailed Plan, rather than to approve such a Plan in its entirety.

Second, the approval process should allow room for revision of the Mission Plan as new information and developments arise. Provision could be made, for example, for the agency to revise and resubmit the Mission Plan for approval as needed.

Third, the approval process must give Congress sufficient ongoing control over the actions and expenditures of the management agency to warrant the relaxation of the normal annual budgetary control. One approach would be to require revision and reapproval of the Mission Plan at regular intervals, such as every 4 or 6 years. Between reapprovals, the waste management agency could be authorized to make expenditures from the Nuclear Waste Fund, as provided for in the multiyear budget contained in the Mission Plan, without a requirement for annual appropriations or authorizations. While the agency would also have the power to propose changes to the Mission Plan and budget more frequently, it might be anticipated that revisions of the Plan and fee would normally take place only at these regular intervals.

Fourth, approval of the initial Mission Plan and revisions to it should be sufficiently difficult that the program and its milestones, once approved, will be taken very seriously, and arbitrary changes will be effectively precluded. To avoid the possibility that the waste management program would come to a halt if the Mission Plan and its multiyear budget were not approved, the program could remain subject to the annual appropriations process unless and until such approval had been granted. The added fiscal independence that would be provided under this approach, if congressional approval of a Mission Plan could be obtained, could give the waste management agency a strong incentive to produce a highly defensible, widely supported Plan.

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[39] The State Planning Council recommended that "national planning for radioactive waste management should avoid abrupt changes in direction to prevent further deterioration of program credibility and loss of time." To that end, it also recommended a broad and extensive national planning process involving all levels of government and the general public. Letter from Richard W. Riley, Chairman, State Planning Council, to President Carter, Jan. 13, 1981. The process of review of the Mission Plan could also serve as a principal vehicle for public information efforts and for public involvement in the waste management program. See discussion of public involvement in ch. 8.

FEDERAL INTERAGENCY COORDINATION

Currently, six major Federal agencies have responsibility for various aspects of the radioactive waste management effort (table 7-3). For any waste management program to succeed and progress according to schedule, each agency must do its job well and on time. Closely coordinated schedules will be required for all involved agencies; working agreements among them will have to be developed; and each agency will have to devote sufficient resources, both money and manpower, to its waste management responsibilities. The challenge of coordination will be more difficult because waste management activities represent only a small part of the responsibilities of each agency.

Table 7-3.—Principal Executive Agencies With Waste Management Responsibilities

Agency/Responsibility

Department of Energy (DOE).—Responsible for developing radioactive waste isolation technologies and for designing, constructing, and operating final isolation facilities for high-level and TRU wastes and spent fuel generated in national defense and commercial nuclear programs.

Environmental Protection Agency (EPA).—Responsible for developing generally applicable standards for radioactive materials. EPA is now developing such standards for geologic repositories for radioactive waste.

Nuclear Regulatory Commission (NRC).—Responsible for developing and implementing regulations to ensure public health and safety for storage and final isolation of high-level radioactive wastes, low-level wastes, and radioactive wastes created in the mining of uranium ore. NRC is now developing regulations for mined geologic repositories that will implement the standards developed by EPA.

Department of Transportation (DOT).—Responsible for developing, issuing, and enforcing safety standards governing certain packaging and shipping containers for radioactive materials, and for the labeling, classification, and marking of all waste packages.

Department of the Interior (DOI):

- ***U.S. Geological Survey (USGS).***—Conducts geologic investigations in support of DOE's waste disposal programs, collaborates with DOE on earth sciences technical activities, and will act as consultant to NRC when NRC considers DOE applications for disposal facilities.
- ***Bureau of Land Management (BLM).***—Serves as custodian of certain Federal landholdings and reviews any proposals to place waste disposal facilities on such lands.

SOURCE: Office of Technology Assessment.

Recognizing the need for cooperation by many Federal agencies to meet mandatory schedules for developing repositories, NWPA requires the Secretary of Energy to prepare "Project Decision Schedules" for each repository specified in the Act. These schedules are to contain deadlines for all Federal agencies that must take action to enable each repository to be developed on time. OTA believes that it would be very useful for the Mission Plan to incorporate the Project Decision Schedules for each repository, so that it would represent an implementation plan for the entire Federal Government, rather than just for DOE. If the initial Mission Plan is submitted before those schedules have been completed, it could be revised as appropriate to include them when they are available.

Development of an integrated radioactive waste management Mission Plan that includes both the technical and institutional steps required for each agency to meet the goals of legislation, as suggested here, would be an important first step toward ensuring interagency coordination.[40] Even after a Plan is developed, there will be a need for continued oversight tc monitor progress and resolve any disputes among the agencies as the Plan is implemented. In addition, action must be taken to ensure that each agency has the manpower and financial resources it will need to fulfill its role in the Federal waste management program. While NWPA provides an assured source of funds for DOE through the waste management fee, the other agencies, which must also act on time if the schedules in the Act are to be met, may be dependent on annual appropriations from general revenues for the funds they will need to do so.

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[40] The State Planning Council concluded that a national plan "is vital to improve coordination among the Federal agencies . . ." State Planning Council on Radioactive Waste Management, *Recommendations on National Radioactive Waste Management Policies: Report to the President*, August 1981, p. 28.

The overall responsibility for developing an interagency plan and overseeing its implementation could be assumed by one of the following groups:

- the lead waste management agency;
- the Executive Office of the President; or
- a high-level council.

OPTION 1:
The lead waste management agency.

As the lead agency for radioactive waste management, DOE has been responsible for coordinating all Federal nonregulatory aspects of waste management and for working out relationships with regulatory agencies. Most waste management legislation considered by Congress has left DOE with interagency coordination responsibilities. IRG also chose DOE to coordinate, plan, and implement the nonregulatory aspects of radioactive waste management. The strongest arguments of IRG in favor of DOE related to the drawbacks of change: a major shift of responsibilities to a different organization could disrupt ongoing programs, cause delay, and entail significant financial costs. Such a change could also exacerbate perceptions that Federal radioactive waste management policy lacks stability.

While DOE can be seen as the logical candidate for overseeing coordination of waste management activities by other agencies, there are some limitations to such an approach. First, the history of the Federal waste program gives some grounds for doubt that sufficient interagency coordination will be achieved in the future if responsibility for coordination is left solely to DOE. Although DOE was given lead agency responsibility and an interagency coordinating committee was established under the Carter administration, no coordinated interagency schedule was developed.[41] The lack of adequate means to set priorities for agencies based on an overall Federal schedule has resulted in such situations as the adoption by the Nuclear Regulatory Commission (NRC) of regulations for repositories in the absence of EPA standards, which the regulations are intended to implement. Similarly, DOE has had to search for prospective repository sites far in advance of determination of the performance standards such sites would have to meet.

The difficulty results in part because some of the key actions in developing waste repositories involve regulatory agencies. While DOE was given responsibility for coordinating all Federal nonregulatory aspects of waste management, its powers over regulatory matters were limited to working out effective relationships with regulatory bodies.[42] Giving DOE full responsibility for coordinating *all* Federal agency activities might create a real or perceived imbalance between the regulated agency (DOE) and the regulator (NRC), particularly if DOE has the power to make the final decision on the deadlines for actions of other agencies, including NRC. To build trust in the Federal Government's waste management program, it may be wise to avoid any actions that could create even the appearance of compromising the integrity of NRC in this area.

This might become particularly important if it were decided to fund the radioactive waste management activities of those agencies out of the Nuclear Waste Fund, rather than from general revenues. Since the fund is not explicitly limited to DOE activities, this may be possible, and it can be argued that this would help ensure steady progress in the waste program. In the current climate of cutbacks in Federal expenditures and manpower levels, there may be budget and staff limitations on the waste management activities of EPA and NRC that could adversely affect their ability to meet schedules. For example, some difficulties can be expected in the first attempt to prove in an NRC licensing proceeding that a repository will perform according to regulatory standards. Delays during that licensing proceeding might be reduced or avoided by an NRC research effort designed to identify and resolve such difficulties before the licensing process begins. Such an effort may be easier to undertake if the necessary funds are provided directly from revenues generated by a mandatory waste management fee than if they must come from NRC's regular annual appropriations from general revenues.

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[41] IRG recognized that "a summary of the implementing actions needed to be taken by involved agencies would have been helpful," and stated that such a summary "is being prepared for submission to the President and will be published subsequently." This was never done. Interagency Review Group, op. cit., p. 119.

[42] "Fact Sheet: The President's Program on Radioactive Waste Management," Office of the White House Press Secretary, Feb. 12, 1980, p. 9.

It can be argued that the incremental increase in the waste management fee that would be required to cover all regulatory activities would be so small that it would not have any impact on the economic competitiveness of nuclear power, and that the cost could be more than offset in the long run if regulatory delays and problems could thereby be minimized. This approach could be facilitated if an integrated Mission Plan also contained long-term cost estimates for the activities of other involved Federal agencies as well as for DOE. However, if DOE had final authority over which costs could be covered by the Nuclear Waste Fund, substantial questions might be raised about the independence of the other agencies funded in that manner.

On the other hand, if the activities of other agencies continue to be funded out of general revenues, it may be impossible for DOE to be effective in ensuring that they have adequate resources to meet their milestones in the Mission Plan. In either case, then, there are questions about whether DOE can play a useful role in dealing with the funding aspects of interagency coordination.

Although the Secretary of Energy is given lead responsibility for preparing the Project Decision Schedules, this task is to be done "in cooperation with all affected agencies." However, the Act does not specify how this cooperation is to be accomplished. In view of the possible limitations of one agency's developing an effective plan for actions required of other agencies, particularly of regulatory agencies, consideration of one of the following options may be useful in developing the interagency Project Decision Schedules, integrating them into the Mission Plan, seeing that they are properly followed, and ensuring that funds are available as needed.

OPTION 2:
Executive Office of the President.

This option would give an existing, high-level organization in the Executive Office of the President responsibility for interagency coordination. For example, the Office of Science and Technology Policy (OSTP) was heavily involved in the activities of IRG, and some have suggested that the Director of OSTP (the Presidential Science Adviser) be designated as the senior policymaker and overall coordinator of Federal activities on radioactive wastes.[43] Such an agency may be free of the credibility problems that have afflicted DOE and its predecessors simply because it is a different organization. Its location in the Executive Office of the President may enhance its chances of achieving coordination among the various agencies involved in waste management and of ensuring that each involved Federal agency has the resources it needs for its waste management activities.[44] If it were decided to fund the activities of the other agencies out of the Nuclear Waste Fund, this approach to interagency coordination could provide a more effective way to allow that to be done without raising questions about the independence of the regulators from the regulated agency, DOE.

On the other hand, there are general disadvantages to giving heavy new responsibilities to an agency in the Executive Office of the President. Agencies in the Executive Office of the President tend to have small staffs, and, as a result, their existing missions could suffer if waste management responsibilities were added. Conversely, existing missions could have such claims on agency loyalties and resources that radioactive waste management could be slighted.

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[43] Keystone Center for Continuing Education, July 1978 Radioactive Waste Management Discussion Group, letter to Frank Press and John M. Deutch, Sept. 9, 1978.

[44] A task force established by the State Planning Council to review a draft of a national plan for radioactive waste management concluded that direct involvement of the Executive Office of the President was needed in preparing the plan and in an interagency management committee. It also emphasized the importance of "active involvement by the Office of Management and Budget to ensure integrated consideration of the programs and budgets for all waste management activities and to generate greater agreement in the executive branch concerning multiyear funding levels presented in the draft plan." "Report for the State Planning Council: An Independent Task Force Review of the Second Working Draft of the National Plan," undated, included as an appendix to a letter from Richard Riley, Chairman, State Planning Council, to President Carter, Jan. 13, 1981. National Academy of Public Administration, op. cit., also recommends designation of "a top echelon position in the Executive Office of the President . . . to serve in the role of an honest broker for the radioactive waste management program" (p. 4).

OPTION 3:

A high-level council.[45]

Several sources have proposed the creation of some type of council structure to handle various aspects of waste management, in particular interagency coordination and planning.[46] While such an approach probably would not be useful for handling operational responsibilities in the waste program, a high-level council might be useful for a more limited purpose such as overseeing the development of an integrated Government-wide Mission Plan that includes the associated Project Decision Schedules and long-term budgets for other agencies. (These budgets would in turn serve as a basis for financing their activities through the Nuclear Waste Fund, if that were desired.) In this approach, the operational responsibility for preparing the detailed contents of the Mission Plan could be left to the appropriate agencies, while the council could guide the development of the outline, oversee the work of the agencies as they prepare its substance, and review and perhaps approve the final product for submission to Congress.

Because of the wide range of interests affected by Federal radioactive waste management activities, the credibility of such a council might be enhanced if its membership included representatives from non-Federal groups such as State and local governments, utilities, public service commissions, and environmental groups.[47] This is commonly done in Presidential or national commissions, such as the Advisory Commission on Intergovernmental Relations or the Water Resources Council, that are appointed to investigate an area of broad national interest.

For such a council to play an effective role in overseeing the waste management planning activities of DOE and the other involved agencies, it would probably need its own staff, focusing solely on radioactive waste management. Its effectiveness might be increased further if it were established formally by Executive order. To avoid creation of a permanent governmental entity, a sunset provision could require dissolution of the council once a Government-wide Mission Plan had been completed. A determination could, however, be made at that time if the council should be continued in some form to oversee the Federal Government's implementation of the program and to ensure that each agency would have both the resources and the incentives to meet its own particular deadlines. (The latter objective might be facilitated if the Office of Management and Budget were included as a member of the council.)

Chairmanship by someone within the Executive Office of the President (e.g., the Vice-President or the Director of OSTP) could both signal a high level of Presidential interest in the resolution of the radioactive waste problem and help preserve the balance between the implementing and regulatory agencies. History suggests that such a council can be an effective focal point for identifying and analyzing, on a coordinated Government-wide basis, the principal options facing the Nation in a particular area of interest[48]—precisely the task that must be accomplished in the development of the radioactive waste Mission Plan. The creation of such a council could be seen as a clear signal to the public that the Federal Government intends to get its own house in order so as to implement NWPA. If such a council were charged with overseeing the development of integrated policies and implementation plans for *all* radioactive wastes, not just commercial high-level waste, it could also help allay concerns of those who fear that legislation dealing only with commercial high-level waste could lead to deferral of action in other areas of waste management.

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[45] The term "council" will be used to refer to any organizational structure involving representatives from various agencies or other groups. Other terms that are frequently used include: committee, commission, working group, task group, etc.

[46] The July 1978 Keystone Radioactive Waste Management Discussion Group recommended that the Interagency Review Group be continued to facilitate interagency coordination. A bill introduced by Senators Percy and Glenn during the 96th Congress (S.742) would have established an interagency committee with duties involving coordination among agencies with waste management responsibilities and preparation of annual Nuclear Waste Management Plans. The State Planning Council Task Force on the national plan recommended that the development of a national plan for radioactive waste management be "aggressively directed by a high-level interagency committee that meets on a frequent basis." This was seen as "necessary to extract and enforce real commitments from the agencies on improved coordination, . . . essential to correcting a key constitutional weakness of the Federal program, and . . . not incompatible with maintaining the necessary degree of independence for regulatory responsibilities." State Planning Council on Radioactive Waste Management, op. cit., p. 4.

[47] A General Accounting Office report that examined the Federal organizational structure for waste management recommended legislation establishing a Federal and State committee to be responsible for developing a national waste management plan. In support of this recommendation, the report stated, "We believe it is very unlikely that making DOE the responsible lead agency to plan and coordinate the program will establish public confidence and trust. A more diverse organizational concept made up of Federal and non-Federal representatives should develop the policy and plan, while DOE maintains responsibility for implementation. Only through this broader involvement can there be any chance that the public can be convinced that an acceptably safe disposal method exists." General Accounting Office, "The Nation's Nuclear Waste—Proposals for Organization and Siting," EMD-79-77, June 21, 1979, p. 12. Along these lines, the National Governors' Association (NGA) Subcommittee on Nuclear Energy once suggested the creation of a National Commission on Nuclear Waste Management, to include members from State and local governments. Statement of Governor James B. Edwards, Chairman of the NGA subcommittee, before the House Committee on Science and Technology, Subcommittee on Fossil and Nuclear Energy Research Development and Demonstration, June 20, 1978.

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[48] See the history of the Space Task Group, established by President Nixon under the chairmanship of the Vice President. *Civilian Space Policy and Applications* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-STI-177, June 1982), pp. 96-98. This group conducted the first interagency planning effort with respect to the civilian space program. It involved participation from the general public as well as Federal agency representatives.

Chapter 8

Addressing State and Public Concerns

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Chapter 8

Addressing State and Public Concerns

INTRODUCTION

History suggests that concerns about the safety and equity of Federal waste management activities on the part of States, Indian tribes, localities, and the general public could become a source of increasingly effective opposition to implementation of a waste management program unless specific steps are taken to deal with these concerns. Efforts to proceed without dealing with them may simply provoke greater resistance, confrontations, and failure to achieve program objectives on schedule. On the other hand, measures that adequately address these concerns in the waste management program are likely to broaden support for it, reduce opposition during implementation, and remove grounds for complaint.

The Nuclear Waste Policy Act of 1982 (NWPA) includes many provisions designed to deal with the concerns of the States, Indian tribes, and the general public. This chapter will describe those provisions and the background against which they were developed.

STATE CONCERNS

The Federal Government must have access to potential disposal sites to evaluate the suitability of various geologic media and of particular sites for radioactive waste disposal. Ultimately, Federal ownership of actual disposal sites will be necessary.

Federal attempts to perform siting activities have met with strong State opposition, however, severely hindering Federal efforts to find and examine potential waste disposal sites across the country.[1] State and Federal apprehensions have led to a vicious circle in which the actions of each side, taken in perceived self-defense, reinforce the fears of the other. On the Federal side, some parties are concerned that States will refuse to take waste under any circumstances. On the State side, there is fear that the Federal Government will site waste facilities despite legitimate State objections.[2]

The manner in which State opposition to Federal radioactive waste management activities is dealt with, and the ultimate outcome of such opposition, have implications for Federal activities in other policy areas in which there is Federal/State conflict. This is especially true in other activities that concentrate costs in smaller areas while spreading benefits on a national or interregional scale. Federal/State relations in radioactive waste management pose both an opportunity to establish mutually satisfactory and workable precedents and a risk of establishing unwise ones.

State opposition to Federal siting activities appears to be based primarily on (1) fears regarding the possible risks and impacts of radioactive waste and waste management activities and (2) fears about possible inequitable distribution of those risks and impacts. These concerns are complicated by distrust of the Federal Government.[3]

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[1] As of September 1982, approximately 160 State laws, initiatives, and resolutions and 250 local laws pertaining to high-level radioactive waste had been passed throughout the United States. Steven H. Murdock, F. Larry Leistritz, and Rita R. Hamm (eds.) *Nuclear Waste: Socioeconomic Dimensions of Long Term Storage* (Boulder, Colo.: Westview Press, 1983), p. 75.

[2] For a discussion of some of the difficulties encountered in past Federal-State relations, see Roger Kasperson, "The Dark Side of the Radioactive Waste Problem," *Progress in Resource Management and Environmental Planning*, T. O'Riordan and K. Turner (eds.) (New York: John Wiley & Sons, Ltd., 1980), vol. 2, pp. 135-136. See also app. A.

[3] OTA's analysis of State concerns draws on the results of OTA staff interviews with State officials in South Carolina, Nevada, New Mexico, and Washington, and on interviews with State officials in Michigan, New York, Illinois, and Tennessee conducted for OTA by the Academy for Contemporary Problems, as reported by Pat Choate and John Bowman in *Radioactive Waste Management: State Concerns*, report prepared for the Office of Technology Assessment, 1980. See also app. A. It should be noted that efforts to find sites for treatment or disposal of nonnuclear hazardous wastes are beset by similar con-

Waste Management Impacts

Radiological impacts—dangers to physical health and safety from exposure to radiation—are the potential impacts of greatest concern to States and localities. No matter how remote the possibility, waste management facilities and transportation of waste bring the chance of accidental release of radioactive materials to the biosphere.

States and localities are also concerned about the nonradiological impacts of waste management activities—i.e., those impacts that can be expected to occur even if there is no release of radioactive materials. Some potential nonradiological impacts, such as demands for increased State emergency response capabilities, arise because radioactive waste management involves radiological hazards. Others arise simply because a nuclear waste management facility is a large-scale industrial activity. Potential nonradiological impacts include the following:

- *Expenditures for activities related to Federal/State relations.* Depending on the arrangements adopted, States will incur costs in reviewing Federal siting proposals, particularly if outside experts are consulted.
- *Increased demands on governmental services.* State and local police and fire departments, health departments, and other agencies will have increased responsibilities to prepare for and cope with possible accidents involving radioactive waste. States may have to allocate additional funds for regulatory activities such as inspection of trucks bearing waste. Roads will be subjected to added stress from truck shipments.
- *Possible losses in land and property values.*
- *Possible losses in tax revenue.* Radioactive waste repositories will be built on land either already owned by the Federal Government or acquired for that purpose. Such lands and facilities will remain federally owned in perpetuity. Traditionally, Federal ownership has meant that lands and facilities are not taxable by State and local governments.
- *Increased demands on potentially scarce natural resources, such as water.*
- *Possible loss of the ability to exploit mineral and other resources from lands surrounding repositories.*
- *Nonradioactive water and air pollution* resulting from facility construction and operation.
- *Boomtown effects.* Construction and, to a lesser extent, operation of radioactive waste management facilities may result in an influx of new residents and transients to areas in which such facilities are located, possibly straining existing physical and social services. Boomtown effects have been severe, for example, in some rural areas of Western States where mining and energy extraction industries have recently begun operations. In some cases, the introduction of a new industry to an unprepared locality has led to social disruption, such as rising rates of alcoholism, divorce, and crime.

Equity

Beliefs about what is equitable vary widely. While the health and safety aspects of prospective waste sites are of primary consideration, the amount of waste present in storage and disposal facilities and the distribution of sites are also important factors in States' views of siting.[4] Some States fear that they could be forced to host radioactive waste generated by the rest of the Nation and thus bear an inequitable share of the disadvantages of nuclear power. Such concerns about equity have been important in the debate over onsite storage v. away-from-reactor storage and in evaluations of repository siting, especially in discussions of numbers and locations of repositories.

Another equity consideration is the length of time waste will be in interim storage in a State. Some States fear that the impetus for the Federal Government to develop permanent repositories would be lessened if such short-term solutions are put into

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cerns. See Martin Jaffe, *Hazardous Waste Management: Implications for Nuclear Waste Facility Siting*, report prepared for the Office of Technology Assessment, American Planning Association, Apr. 18, 1980.

[4] Concern about equity was expressed by many State officials in interviews with OTA staff and has been frequently expressed in congressional hearings on radioactive waste legislation. See, for example, statements made by officials from Illinois and South Carolina to the Senate Environment and Public Works Subcommittee on Nuclear Regulation during hearings concerning pending nuclear waste legislation on Nov. 9, 1981.

place, and that, as a result, interim spent fuel storage in those States could become permanent by default.[5]

Federal Credibility

Distrust of the Federal Government, stemming from past instances of what States perceive to be low Federal competence and poor responsiveness to States' needs, forms the background against which States express fears about impacts and equity and from which States measure current Federal efforts.[6] State opinion of Federal competence has been lowered by frequent Federal policy changes; delays in formulating a stable national radioactive waste management plan; failure to consult effectively with State officials on site investigations; several controversies about the scope of the Waste Isolation Pilot Plant, near Carlsbad, N. Mex.; maintenance and funding of the contaminated Nuclear Fuel Services reprocessing plant site at West Valley, N.Y.; and the safety of the proposed site at Lyons, Kans. Problems with leaks and inadequate monitoring of military and low-level waste have also affected State perceptions of Federal management of commercial high-level radioactive waste. One State fear is that considerations other than technical criteria bearing on safety will play an unwarranted role in Federal siting decisions. Such considerations might be, for example, a perceived need for rapid siting of a repository to remove the waste problem as an obstacle to nuclear power, or a desire to save costs and time by directing site-selection efforts toward locations with already existing Federal facilities.

NWPA addresses State and Indian tribe concerns through measures in three areas: State involvement in waste management decisions, prevention and mitigation of impacts of waste management activities, and equity in siting waste facilities.

STATE INVOLVEMENT IN WASTE MANAGEMENT DECISIONS

Discussions about State involvement in radioactive waste management have focused on two areas:

1. How States should be involved in making overall Federal radioactive waste management policy and in reviewing implementation of policy.
2. What powers a State should have in siting decisions involving that State, and what limits should be placed on those powers.

State Role in Policy Development and Program Oversight

States have played a role in the formation of Federal radioactive waste management policies and in the review of implementation of those policies by the same means as those used in other policy areas: discussions with agency officials, direct lobbying of administration and congressional leaders, and use of the State's congressional delegation to make views known and to influence policy. Organizations representing State governmental groups, such as the National Governors' Association and the National Conference of State Legislatures, have also been important in advocating State interests.

In addition to these traditional means, States were involved in the development of Federal radioactive waste management policy through a special-purpose organization, the State Planning Council (SPC), created by President Carter by Executive order in February 1980 and given an 18-month maximum lifespan. SPC, among other duties, made recommendations to the President and the

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[5] Officials in both South Carolina and Illinois were concerned that proposed Federal interim spent fuel storage in existing facilities in those States could become permanent if there were continued delays in a Federal permanent repository. They also did not want such interim storage facilities to take a disproportionate share of the national spent fuel storage burden. See *Federal Facilities for Storing Spent Nuclear Fuel—Are They Needed?* General Accounting Office, June 27, 1979, EMD-79-82, pp. 14-16. See also E. William Colglazier, Jr. (ed.), *The Politics of Nuclear Waste* (New York: Pergamon Press, 1982), especially the Foreword by Governor Richard W. Riley of South Carolina, pp. ix-x.

[6] See app. A; and Choate and Bowman, op. cit.

Secretary of Energy about State involvement in all phases of radioactive waste siting and on more general matters of policy affecting State and local interests, such as composition of the National Waste Management Plan and the Nuclear Regulatory Commission's (NRC) licensing procedures. SPC formally dissolved in August 1981 after issuing a final report.

Some proposals for future State involvement in radioactive waste management have envisioned the recreation of SPC or the creation of a similar organization; others have focused exclusively on the State role in siting decisions, leaving State involvement in policymaking to traditional means.

It can be argued that with the completion of the assigned duties of SPC, there is no longer a need for a special-purpose organization to supplement existing ways in which States can contribute to Federal radioactive waste management policy. Within SPC itself, there was division about whether the council's life should be extended, and no resolution was passed calling for such an extension.

In favor of reviving SPC or creating a similar organization, it can be argued that there is a continuing need for a single body to synthesize the viewpoints of different States and of groups within States. Radioactive waste management policy could experience major changes under different Presidential administrations during the extended period in which waste management facilities will be sited and operated. A special-purpose organization could prove useful for reviewing and commenting on the draft radioactive waste Mission Plan to be prepared pursuant to NWPA, for monitoring the waste program, and for making recommendations when appropriate.[7] Another possible avenue for State involvement in policy development and program oversight would be State representation on broader bodies such as a high-level council for overseeing development of a Federal Government-wide Mission Plan, or an oversight body for an independent waste management agency. (Further discussion of these ideas is found in ch. 7.)

NWPA made no special provision for State involvement in policy development and program oversight, although it does specify that the draft Mission Plan must be submitted to the States and affected Indian tribes for their comments. However, it may be useful for the administration to consider establishing some mechanism through Executive order, as was done with the SPC, and for congressional deliberations on alternative management approaches to consider a State role in oversight of the institutional options that are considered.

State Role in Facility Siting Decisions

The question of the appropriate role for States and Indian tribes in Federal decisions about siting radioactive waste management facilities has been one of the main areas of contention in development of Federal radioactive waste management policy. The Carter administration proposed giving States a continuing role in radioactive waste management through a process termed *consultation and concurrence*.[8] This policy left many specific features of the Federal/State relationship undefined, however. Later, proposals setting out the State role more clearly were introduced in the 96th Congress, and both the Senate and House passed radioactive waste management bills (S. 2189 and H.R. 8378, respectively) in 1980 which specified provisions for State involvement, although no final bill was adopted at that time. NWPA, passed in the closing days of the 97th Congress, contained detailed provisions for State involvement in siting not only permanent disposal facilities, but also facilities for interim spent fuel storage and for certain research and development (R&D) activities. These are discussed below.

There has been general agreement that a process of consultation—in which individual States are promptly and continuously provided information about intended siting activities affecting them, State views are solicited, and Federal responses are made to State concerns—should take place. NWPA provides for such consultation in two general ways. First, it specifies points during the repository site screening and licensing process at which the affected

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[7] The RESOLVE Forum on High-Level Radioactive Waste Management recommended continuation of SPC. See *Managing the Nation's High-Level Radioactive Waste: Key Issues and Recommendations* (Washington, D.C.: The Conservation Foundation, July 1981), pp. 27-28.

[8] For a discussion of the genesis of this concept during the deliberations of the Interagency Review Group (IRG), see Ted Greenwood, "Nuclear Waste Management in the United States" in Colglazier, op. cit.

States and Indian tribes must be notified of proposed Federal actions, provided with detailed information, and given a chance to comment (see table 8-1). Second, it requires the Secretary of Energy to seek to enter into binding written agreements with States or Indian tribes affected by Federal activities at sites that have been selected for detailed characterization. These agreements are to include a wide range of specified procedures, including procedures: 1) by which a State or Indian tribe may study and make recommendations concerning the impacts of a proposed repository; 2) by which the Department of Energy (DOE) shall assist the State and local governments near the repository site in resolving concerns about such offsite effects as emergency response requirements, waste transportation, and monitoring of the repository during operation and after decommissioning; and 3) by which the objections of a State or Indian tribe can be resolved through negotiation, arbitration,

Table 8-1.—NWPA Decisions, Deadlines, Opportunities to Influence

Decision/event	NWPA deadline	Opportunity to influence
Draft Mission Plan published by DOE	Apr. 6, 1984	Reviewed by State/tribe Comments available for public inspection
Final Mission Plan submitted to Congress	June 6, 1984, effective 30 days after submission	
Five sites nominated for site characterization	After issuance of siting guidelines (R1)[a] July 1, 1989 (R2)[a]	Hearings in vicinity of sites prior to nomination and prior to preparation of environmental assessments
Environmental assessments for five nominated sites	Accompany nominations	
Three sites recommended for site characterization	Jan. 1, 1985 (R1) July 1, 1989 (R2)	
President approves or disapproves three sites for site characterization	2 to 6 months after recommendation	
Site characterization plans (SCPs) prepared by DOE for each site to be characterized	Prior to sinking exploratory shafts	Public hearings State/tribal comments on draft SCPs, SCPs available for comment at hearings
NRC site characterization Analysis for each site		State/tribal comments on draft
	Prior to repository site recommendation	DOE must hold hearings at all sites under consideration for repository recommendation
	30 days prior to recommendation	DOE must notify State/tribe State/tribe may comment to DOE and provide impact report to be forwarded to the President
DOE recommends one site for repository		
DOE prepares environmental impact assessment		Public comment on draft environmental impact statement
President recommends site to Congress	Mar. 31, 1987 or 1988 (R1) Mar. 31, 1990 or 1991 (R2)	
Possible State/tribal notice of disapproval to Congress	60 days later	State/tribal action (may include public participation if no written agreement)
Possible congressional override	90 days later	
DOE submits application to NRC for construction authorization	90 days after site designation takes effect	Application sent to State/tribe
NRC issues construction authorization	Jan. 1, 1989 (R1), or 3 to 4 years after receipt of application (R1, R2)	Intervention in licensing
Repository in operation	1998 (R1)	

[a] R1 refers to the first repository; R2 to the second.

SOURCE: Laura Worby, *Citizen's Nuclear Waste Manual* (Washington, D.C.: Nuclear Information and Resources Service, 1984).

or other mechanisms. Similar mechanisms and procedures are provided by the Act for consultation with States and affected Indian tribes concerning siting and operation of Federal interim storage facilities, any monitored retrievable storage facilities that might subsequently be authorized, and test and evaluation facilities.

Perhaps the most controversial question concerning the State role in waste facility siting was how much formal power, if any, the States should be given to block Federal actions. The alternatives that were considered ranged from giving States an absolute veto—i.e., the binding legal authority to halt Federal siting activities—to giving the Federal agency responsible for waste management the explicit authority to preempt State objections. This section will discuss some of the principal arguments for these two positions, which represent the opposite ends of the spectrum of alternatives, and will describe the provisions for shared powers that were ultimately incorporated in NWPA.

State Veto—the Binding Legal Power to Halt Federal Siting Activities

Under a State veto approach, Federal agencies could proceed with activities only in the absence of State objections. The most important feature of this approach is the binding legal power of a State to stop the activity in question at any point. Such activity could resume only if the State changed its position.

As argued by proponents, veto rights represented an equitable and constitutionally justified distribution of power among political units. If errors were made in the siting, design, construction, or operation of radioactive waste facilities, present and future residents of States would have to live with the consequences. Historically, States have been accorded primary responsibility for protecting their citizens' property, health, and general welfare. Veto power was seen by some as a necessary defense against a Federal Government perceived as prepared to site radioactive waste facilities regardless of State objections.

In addition, many advocates of State veto believed that States would act reasonably and that a veto would not be used unless it were essential. In their view, a veto would indicate an unreasonable or unsafe Federal proposal rather than an unreasonable State reaction. They expected that siting would occur if the Federal Government could provide credible assurances of safety. A situation in which all 50 States vetoed sites was not anticipated. Advocates believed that, even if the situation were likely, the veto approach should be rejected only if and when the situation occurred, and not before.

On the other hand, not only Federal officials, but many State officials as well, feared that if given a veto power, State officials would have no choice but to use it, regardless of the merits of a particular project.[9] They believed the alternative to such use could be political disaster because public opposition to a radioactive waste project is likely to be much stronger and more intense than support for it. Even if internal political pressures were not overwhelming, officials might use their veto power out of fear that their State would be the only one not to veto a facility. If use of the veto by many States was expected, the Federal Government might select sites primarily on political rather than technical grounds—one of the very reasons why some States distrust the Federal Government. For these and other reasons, the veto approach was opposed by many organizations, including SPC.[10]

Federal Agency Preemption

Federal agency preemption—whereby a Federal agency could, if necessary, overrule a State and proceed with a siting activity in dispute—is the reverse of State veto. In essence, the extent of involvement and power possessed by States would be determined by the Federal Government. In its extreme form, States would have little or no chance to influence Federal activities, and consultation would be minimal. More commonly, however, proponents of the preemption approach envisioned much greater State involvement, including measures of consultation. Even with extensive consultation, however, Federal agency power would remain clearly predominant.

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[9] For example, statement by Steven Sklar for the National Conference of State Legislatures before the Subcommittee on Energy Regulation, Senate Committee on Energy and Natural Resources, July 19, 1979, p. 8

[10] State Planning Council on Radioactive Waste Management (SPC), *Recommendations on National Radioactive Waste Management Policies: Report to the President*, August 1981, p. 6.

Several rationales were given for preemption. Preemption was seen by proponents as the appropriate expression of Federal preeminence in radioactive waste management, given the relationship of waste management to other areas of Federal concern, such as national energy policy, interstate commerce, foreign policy, national health, and distribution of costs among many States. It also was seen as consistent with past Federal legislation and policy in the general field of atomic energy.

An implicit assumption behind preemption, in many cases, was that a significant number of States would reject siting of a radioactive waste facility, given the power to do so. In this view, making compromises with a State would take too long or be too expensive to permit timely siting of needed waste management facilities. Examples that support this assumption include the many State laws restricting waste management activities and vociferous State reactions even to initial site exploration. An explicit declaration of Federal power was perceived by some proponents to be the quickest and, perhaps, only way to remove such present and potential obstacles to siting activities in time to safeguard nuclear power.

Opponents noted that preemption had potential problems as an approach to State powers in radioactive waste management. Apart from objections based on States' rights considerations, the ability of this approach to overcome State objections quickly may in fact be limited. States have substantial abilities to translate their objections into delay and expense for the Federal Government through such means as defense of their legislation in court and intervention in licensing hearings. While the Federal Government's legal power to overcome State opposition is fairly clear,[11] the amount of time and expense required to do so is uncertain. Court challenges, for example, could take years to reach judgment.[12] Some feared that unless the avenues for State intervention were narrowed or the procedures for reviewing challenges to State actions were expedited—measures that could have broader implications for Federal/State relations in general—attempts at preemption might make siting proceed more slowly. Preemption could also create a vicious circle in which preemption of initial State opposition would generate more intense opposition, which in turn would have to be preempted. Each turn of the circle would make it more difficult to return to mutual trust. Initial use of the preemption approach could make it difficult to switch to a more cooperative approach later.

Shared Powers

Between preemption and veto, a broad spectrum of possible approaches to Federal/State sharing of power in radioactive waste management were considered in the debate leading up to passage of NWPA. This report will use the term *shared powers* to characterize this middle ground.

Basic features of most proposals for shared powers that were considered included: 1) extensive consultation between States and the Federal Government, often including procedures for resolving some types of State objections (e.g., by arbitration); and 2) the formal ability of States to halt some Federal siting activities, under some circumstances, balanced by Federal power to override State objections, given certain conditions. Shared powers thus represented a compromise between veto and preemption, with limitations placed on the powers of both sides.

Limitations on State power, especially override provisions, are objected to by some defenders of States' rights because of the perceived chilling effect such limitations might have on a State's ability to influence Federal actions and to protect State interests. Conversely, even with such limitations, some observers are troubled by the formal ability of States to halt Federal projects. These disadvantages to each side are mitigated by several factors. From the State perspective, limitations on veto power may be acceptable even to strong defenders of States' rights. At the same time, defenders of Federal preeminence may find satisfaction even in a process that gives States nonconcurrence powers under some circumstances.

The Carter administration policy of consultation and concurrence, while intended as a compromise between the extremes of preemption and veto, was vague in its definition of concurrence, particularly in distinguishing between nonconcurrence—the ability of a State to prevent the continuance of Federal siting activities—and State veto.[13] Not surprisingly, much of the debate about the State role in radioactive waste management during the 96th and 97th Congresses focused on the precise specification of the balance between Federal and State authority.

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[11] For a general discussion of the legal status of State laws affecting radioactive waste management, see Harold P. Green and L. Marc Zell, "Federal-State Conflict in Nuclear Waste Management: The Legal Bases," in Colglazier, op. cit.; and William C. Metz, "Legal Constraints to Repository Siting," in Murdock et al., op. cit.

[12] Frederic A. Morris, "The Federal Legal Framework for High-Level Nuclear Waste Management" (Seattle: Battelle Human Affairs Research Center, Mar. 31, 1980), BHARC-311/80/009, pp. 29-34.

In response to those who were concerned about giving States any formal authority to halt Federal activities, it was noted that adoption of explicit procedures for shared powers would in some ways be simply a formalization of powers States already possessed to delay Federal actions, plus formalization of procedures for resolving disputes at several levels. It was argued that these formalizations would make the use of State power more predictable and contained. Federal plans, State objections, Federal responses, mediation between parties, and final judgments could all be expressed within specified areas with prescribed procedures and time limitations. Adoption of a formal structure in law might enable the Federal Government to avoid the slow, graduated appeal procedures likely in various courts if restrictive State actions were challenged and defended.[14]

Procedures Established by NWPA

NWPA includes detailed processes for State and Indian tribe involvement in decisions for siting the different types of waste management facilities addressed in the Act. While there are some differences in the processes dealing with different facilities, in general they share two features: 1) prior to selection of a final facility site, State and Indian tribe participation is limited to extensive consultation; and 2) following site selection[15] by the Federal Government, the affected State or Indian tribe has the right to lodge a formal objection with Congress, and that objection becomes effective unless overturned by passage of a joint resolution by both Houses of Congress. These and several other features will be discussed briefly next.

State role during site exploration and characterization.—NWPA provides for extensive consultation with States during the siting steps preceding the President's recommendations to Congress of a site for a repository, but the Act grants the States no authority to halt Federal activities. During the debates on waste management legislation, some had argued that States should have the right to forbid or halt these initial siting activities, as well as some other activities, because of the possibility that site exploration might lead eventually to a repository. Others argued that such restrictions on exploration could mean that sites that were desirable from a technical viewpoint might be effectively withdrawn from consideration, or that the sites that were finally chosen might be those that were most politically acceptable rather than those that were most technically suitable.[16] If safety is to be the primary goal of radioactive waste management policy, it was argued, the ability to gain knowledge about different media and sites must be preserved, and therefore the States' ability to prevent the Federal Government from conducting site exploration activities should be limited.[17]

Procedures by which the Federal Government could override a State's objection.—The 96th and 97th Congresses debated extensively about what procedures should be required to override a State's objections to a Federal choice of a waste disposal site. The greater the number of political bodies required to reach agreement to override a State objection, and the greater the amount of action required by them, the more difficult it will be for an override to occur. SPC, for example, recommended that for a State's objection to be voided, a Presidential determination and a concurrent or joint resolution by both Houses of Congress should be required.

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[13] The Interagency Review Group stated that consultation and concurrence implies "an on-going dialogue participation and the development of a cooperative relationship between States and all relevant Federal agencies during program planning and the site identification and characterization programs on a regional basis using the systems approach, through the identification of specific sites, the joint decision on a facility, any subsequent licensing process and through the entire period of operation and decommissioning. Under this approach the State effectively has a continuing ability to participate in activities at all points throughout the course of the activity and, if it deems appropriate, to prevent the continuance of Federal activities." (*Report to the President by the Interagency Review Group on Nuclear Waste Management*, TID-29442, March 1979, Washington, D.C., p. 95.) For further discussion of the concept of consultation and concurrence, see *Consultation and Concurrence*, proceedings of a workshop held at Eastsound, Mich. on Sept. 23-26, 1979, published by the Office of Nuclear Waste Isolation, Battelle Memorial Institute, January 1980, ONWI-87.

[14] Sklar, op. cit., p. 2.

[15] In the case of a Federal Interim Storage Facility, the State has the right to object only after DOE decides to provide more than 300 tonnes of storage capacity at a site.

[16] Sklar, op. cit., p. 5.

[17] In this regard, SPC recommended that States and tribes not arbitrarily refuse permission for initial site investigations. SPC, *Interim Report*, Feb. 24, 1981, p. 14.

Conversely, override can be made easier in various ways. Both the Senate and House bills passed in the 96th Congress had provisions stating that for a State's objection to stop DOE's civilian waste siting activities effectively, at least one House of Congress must pass a resolution sustaining the State's objection. State objections would thus be overridden de facto if such a resolution were not passed.

After considering and finally rejecting the "one-House-sustain" approach, the 97th Congress ultimately agreed to include in NWPA a procedure requiring passage of a joint resolution by both Houses of Congress to override a State's objection to a Presidential selection of a repository site. However, the "two-House-override" approach may be little different from the "one-House-sustain" approach in terms of the relative difficulty of overturning such an objection. The reason is that the procedures in NWPA for congressional consideration of a State's objection practically ensure that both Houses would ultimately have to vote on a resolution dealing with that objection, as was the case with the "one-House-sustain" provisions previously under consideration. As long as each House will eventually have to vote on the question of whether to sustain or overturn a State's objection, all the State has to do to have its position upheld under either approach is to persuade one House to vote its way.[18] However, if the procedures had allowed a significant possibility that one House might never vote on the question (for example, if the resolution could die without being discharged from a committee to which it had been referred), the legislation would have been biased in favor of continuation of the status quo if Congress failed to act—rejection of a proposed site in the case of a "two-House-override" approach, or acceptance of the site with a "one-House-sustain" approach.

Participation by affected States and local governments.—Affected States are those that could be heavily affected by a radioactive waste management facility located in another State: e.g., States that are connected by above- or below-ground water systems or that serve as a transportation corridor for waste shipments to another State in which a waste facility is located. Some proposed giving affected States rights similar to those enjoyed by host States. SPC, for example, recommended that affected States meeting certain criteria established by DOE in consultation with the Department of Transportation (DOT) have rights equivalent to host States.[19] However, NWPA gave explicit participation rights only to States that would host a repository site and to affected Indian tribes.[20]

Localities near radioactive waste management facilities will bear a large share of facility-related impacts. While there were many proposals that relevant local governments be given consultation rights, there were few proposals that they be given any authority to block Federal actions, as well. State officials and organizations have generally been opposed to giving local governments such authority. NWPA does not provide for participation in siting decisions by units of local government, and leaves it up to States to decide how local governments will be involved in the consultation process.

A recent National Research Council report concluded that the lack of an institutionalized process for involving local governments in the siting process represents a significant gap in the framework defined by NWPA, and that the need for linkage between local jurisdictions and State governments is of potentially critical importance to the waste management program. The report underscored the responsibility of State governments to address the issue of State-local relations constructively, since Congress decided against a Federal prescription for the institutional relationship between State and local governments.[21] On this topic, SPC had recommended that the Federal Government put forward a clearly structured interagency waste management program plan that provides for effective participation by local governments, as well as by State and tribal governments.[22] In addition, it recommended that States establish a process that would enable local governments to participate in the NRC repository licensing process.[23]

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[18] If the one-House-sustain approach is used, a House sympathetic with the State would vote to pass the resolution to sustain the objection. If the two-House-override approach is used, a House sympathetic with the State would vote to defeat the resolution to override the State objection. In either approach, the State objection would be overridden only if both Houses supported the selection of a site by voting to defeat a resolution to support the State or to pass a resolution to override the State. If either House does not support the site selection under either approach, the State's objection would be sustained.

[19] SPC, *Interim Report*, p. 19.

[20] NWPA defines an "affected Indian tribe" as one whose reservation contains a specified radioactive waste facility or whose federally defined possessory or usage rights may be substantially and adversely affected by the locating of such a facility. (42 USC 10101.)

The State role in military waste siting.—There was substantial disagreement over whether States should have the same role in military waste disposal as in civilian waste disposal efforts. Some argued that because the hazards associated with defense and commercial waste are similar, their treatment should be similar. In addition, some feared that if commercial and defense waste were considered separately, defense waste might remain in storage indefinitely rather than be disposed of safely. Others argued that giving States a role in decisions on the disposal of military waste would jeopardize national security and could set a precedent for involving States in decisions on siting other facilities needed for national security purposes, such as military bases.

One compromise considered was to give States the power to object to military waste facility siting but to make override easier than would be the case for the siting of commercial waste facilities. For example, S. 2189, considered during the 96th Congress, required that a State's objection to defense waste siting could be upheld only if both Houses of Congress affirmed the objection. However, the 97th Congress agreed in NWPA to apply the same procedures to repositories for commercial waste and defense waste. NWPA also provided that the Secretary of Energy use the commercial waste repositories developed under the Act for disposal of defense waste, as well, unless the President finds, on the basis of an evaluation to be completed by January 1985, that a separate repository for defense waste is required. The draft of that evaluation, released in 1984, concludes that disposal of defense waste in commercial repositories would be the most cost-effective option.

PREVENTION AND MITIGATION OF IMPACTS

State concerns may also be addressed directly in the waste management program by measures dealing with the prevention and mitigation of impacts. Such measures could reduce pressures on the participation process (above) as the principal means of protecting States' interests. They could also increase State confidence in the competence and integrity of the Federal radioactive waste management system.

Addressing State Concerns About Safety

It is beyond human ability to ensure that no release of radioactivity will occur over the course of radioactive waste management operations and during the long life of the waste after it is disposed of; indeed, such total containment is not required by the proposed Environmental Protection Agency (EPA) standards nor final NRC regulations for high-level waste repositories. However, it is possible to reduce the chances that serious impacts will occur and to lower the consequences of impacts if they do occur. States seek assurances that siting will not be based on nontechnical grounds or inadequate criteria, that the siting process will proceed no faster than safety concerns dictate, that waste management activities will be monitored for safety, and that emergency response capability exists. The Federal radioactive waste management program could provide such assurances in several ways. Some are explicitly provided by NWPA, while others are within the discretion of DOE.

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[21] National Research Council, *Social and Economic Aspects of Radioactive Waste Disposal: Considerations for Institutional Management* (Washington, D.C.: National Academy Press, 1984).

[22] SPC, *Recommendations*, p. 12.

[23] Ibid., p. 15.

Independent Reviews of Radioactive Waste Management Plans and Activities

Confidence in the safety of waste management activities will be increased by independent reviews of Federal plans for radioactive waste management before such activities take place. At present, there are three main levels planned for such review—internal review by DOE, licensing proceedings by NRC, and reviews by individual States of applicable parts of the plan. Additional levels of review (e.g., by bodies of independent scientific experts) might increase the confidence of observers that sites, technologies, and management systems will meet necessary levels of safety and reliability.

NWPA provides States and affected Indian tribes with funding for such independent technical reviews. The Environmental Evaluation Group in New Mexico provides a good example of how such review might be accomplished. This group, which is supported by funds from DOE, provides the State of New Mexico with independent technical review of DOE activities in developing the Waste Isolation Pilot Plant near Carlsbad.

As discussed in chapter 3, the first repository could well become an international waste disposal research center. In that event, opening the repository to independent scientific investigations could give the affected State and locality additional confidence that potential problems with the site would not be overlooked.

Availability of Backup Sites

States' concerns that the Federal Government might continue to develop a less-than-satisfactory repository site simply because of the lack of any alternatives could be addressed by measures designed to increase confidence that an adequate number of backup sites would be under consideration at each stage of the repository development process, up to and including full-scale operation. Along these lines, NWPA establishes a process for siting and licensing two separate repositories. The site for each is to be selected based on (1) an initial evaluation of five sites that have been nominated for consideration on the basis of preliminary data obtained from surface exploration and drill holes, and (2) a detailed characterization at repository depth of three of the nominated sites.

Additional measures that could be provided by DOE in the Mission Plan include a target date for operation of the second repository soon after the opening of the first, characterization of one more site than the required three, and submission of a backup site for licensing for each repository. These measures—which are also needed to increase confidence in a firm waste acceptance schedule, as discussed in chapter 6—could increase confidence that any sites eventually selected for development had been chosen strictly on technical merit,[24] and could also deal with State concerns about equity in siting by assuring States that the initial site would not automatically become the only operational site.

Assistance in Monitoring and Emergency Response

The capabilities of personnel and equipment to detect and respond to accidents are important for maintaining the safety of radioactive waste management operations. Filling the need for these capabilities may be the impact of radioactive waste siting that affects the largest number of States and communities, depending on waste transportation arrangements.[25] Every State and community through which waste will be transported will need some ability to respond to accidents, or at least to know whom to contact if local capability is inadequate. Monitoring and emergency response capabilities are also necessary for the safety of waste management facilities during operation and after closure. The Federal Government will have the primary responsibility for monitoring any emergency response at Federal facilities, although States will be involved to some extent.

NWPA provides for assistance to repository host States and affected Indian tribes concerning monitoring and emergency response for both waste transportation and repository operation. However, no provision is made for special assistance to nonrepository States affected by waste transportation. Thus, such States will have to rely on existing general provisions for Federal involvement in transportation of radioactive materials.

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[24] Choate and Bowman, op. cit., pp. 25-26.

[25] See Albert M. Church and Roger D. Norton, "Issues in Emergency Preparedness for Radiological Transportation Accidents," *Natural Resources Journal*, vol. 21, No. 4., October 1981, pp. 757-771.

Under legislative authority that existed prior to passage of NWPA, NRC and DOT regulate the transportation of radioactive waste. However, State and local authorities, along with personnel employed by transportation carriers, are usually the first to respond to transportation accidents involving all types of hazardous cargo shipments, and they have primary responsibility for maintaining public health and safety in the event of such accidents. This is true for radioactive waste transport, as well.[26] The Federal Government provides assistance to State efforts in various ways: for example, through radiological assistance teams, training courses for State and local authorities, assistance to States in preparing emergency response plans, and funding of state enforcement efforts through the State Hazardous Materials Enforcement Development Program conducted by DOT.[27]

Monitoring—which includes inspection, enforcement, and, possibly, escort of waste shipments—and emergency response policies and capabilities vary greatly from State to State.[28] Some States have wide-ranging requirements and large offices devoted to one or both efforts; others have more minimal requirements and may depend largely or entirely on outside assistance. For both emergency response and monitoring, the ability of States to handle shipments depends, in part, on regulatory demands. For example, if Federal regulations requiring waste to be escorted were to be promulgated, a heavy burden could be placed on State and local police departments.

Some States feel that their programs are adequate to handle foreseeable demands. However, other States and localities see some level of Federal assistance as necessary. Localities, in particular, often lack equipment and expertise to deal with emergencies involving radioactive materials, and many States express a desire for aid in training personnel and in procuring special equipment. Opinions vary on what the extent of Federal assistance should be. SPC recommended that State and, where appropriate, tribal governments should have the lead role in developing emergency response plans and procedures for dealing with transportation accidents.[29] Consideration of additional Federal support to States affected by radioactive waste transportation may be appropriate before large quantities of waste begin to be moved to an operating repository. Options include:

1. Additional Federal backup to State and local efforts, such as training programs, provision of information, or more active support in equipment and personnel.
2. Increased level and scope of Federal funding of State and local efforts. Financial assistance may be needed to enable States to cope with the relatively large number of shipments of radioactive waste that will occur when a repository begins operating. For example, it has been estimated that it would cost about $6 million over 30 years for the equipment and training needed to bring New Mexico's emergency response capacity to the level required for the anticipated shipments of transuranic waste to the WIPP facility.[30]
3. Direct provision of monitoring and emergency response services.

Impact Mitigation

Many of the nonradiological impacts likely to arise from the management of radioactive waste are common to other large-scale industrial developments and could be significant for the States and communities involved, depending on the size of repositories, the size of the affected communities, and the proximity of communities to repositories. DOE has said that potential impacts on communities near proposed repository sites represent a significant issue in gaining public and local acceptance of siting activities.[31]

SPC recommended that, because the Federal Government has responsibility for developing repositories, it should accept responsibility for socioeconomic impacts arising from such development.[32]

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[26] Ibid., p. 765.

[27] S. N. Salomon, *State Surveillance of Radioactive Material Transportation*, U.S. Nuclear Regulatory Commission, Office of State Programs, NUREG-1015, February 1984, pp. 35-36.

[28] For a detailed review of existing State programs, see ibid.

[29] SPC, *Recommendations*.

[30] R. Cummings, H. Burness, and R. Norton, *The Proposed Waste Isolation Pilot Project (WIPP) and Impacts in the State of New Mexico: A Socioeconomic Analysis* (Albuquerque, EMD-2-67-1139, April 1981), ch. 7; cited in Church and Norton, op. cit., p. 764.

[31] Statement of Kenneth Davis, Deputy Secretary of Energy, before the Subcommittee on Energy and the Environment, Committee on Interior and Insular Affairs, U.S. House of Representatives, July 9, 1981. Interior and Insular Affairs Document 97-12.

Measures to mitigate the impacts of repository siting activities may be vital in making those activities acceptable to the affected population.[33] Without mitigation measures, a major portion of the costs of siting would be borne by host States and communities. While such concentration of costs is common, radioactive waste management may be judged differently from other industrial activities. One major difference lies in the perceived benefits brought by the siting of facilities. Apart from the general national importance of isolating waste safely, the principal specific benefit of commercial radioactive waste management will be the continued viability of nuclear power—a benefit that may not be experienced directly by affected areas.

On the positive side, some jobs will be created and some local businesses will benefit, especially with the construction of repositories. There may be long-term beneficial impacts on the community if the repository becomes an international scientific research center. However, these local benefits may not by themselves outweigh local concerns about the potential negative impacts of a radioactive waste repository.

NWPA includes a number of requirements for a range of payments to host States, affected Indian tribes, and, in some cases, units of local government to mitigate the impacts of development and operation of the various facilities provided for in the Act. Drawing these payments from the Nuclear Waste Fund, rather than from general revenues, should substantially increase the credibility of Federal assurances that mitigation payments will be forthcoming when needed. A brief discussion of three types of impact payments follows.[34]

Tax-Equivalent Payments

Because waste disposal will be conducted by the Federal Government, the land, facilities, and operations will not be subject to the State and local taxation that normally offsets some of the costs of private industrial activities While other Federal facilities share this drawback, radioactive waste management operations are less attractive. Unlike many other Federal lands, which are at least potentially returnable, waste sites will never be turned back to lower units of government. To deal with this, NWPA includes a requirement for payments to States and units of local government in which a repository is located, and to Indian tribes affected by repository development, of an amount equivalent to the revenues that would be collected if the repository could be taxed at the same rate as other real property and industrial activities. In the case of Federal interim storage facilities, general impact assistance payments can be used to compensate for the loss of taxable property resulting from public rather than private ownership of the facilities. No provision is made for tax-equivalent payments in the case of monitored retrievable storage facilities or test and evaluation facilities.

Compensation Payments

There are many precedents for compensating affected units of government monetarily for direct impacts caused by private or Federal activities and for making anticipatory payments in expectation of such impacts.[35] Firms planning to conduct operations such as extraction and development of natural gas, coal, oil, shale, and minerals have offered lump sum payments and other mitigation measures, such as direct funding of services, to offset both actual and anticipated impacts. Nuclear utilities in several countries also offer such measures to affected communities. In Japan, for example, anticipatory compensation payments are made prior to evidence of damage. Localities receive a subsidy—portions of which go to improve roads, schools, and other public projects—generated from a tax on utilities for electrical generation.[36] NWPA includes provisions for impact mitigation payments to States in which a repository is located and to affected Indian tribes. State participation in forecasting potential impacts arising from radioactive waste management activities and in negotiating Federal mitigation measures are included in the guarantees provided by NWPA.[37]

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[32] SPC, *Recommendations*, p. 11.

[33] A more extensive discussion of mitigation measures can be found in chapters 10, 11, and 12 of Murdock et al., op. cit.; see also S. A. Carnes et al., *Incentives and the Siting of Radioactive Waste Facilities* (Oak Ridge, Tenn.: Oak Ridge National Laboratory, ORNL-5880, 1982).

[34] A more detailed description of the mitigation measures contained in NWPA and an evaluation from a State point of view are found in "The Nuclear Waste Policy Act and Socioeconomic Impact Mitigation Provisions and Problems," by Robert D. Smith of the Texas Nuclear Waste Programs Office, published in *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting,* U.S. Department of Energy, CONF-831217, February 1984, pp. 50-56.

[35] This was done, for example, when the Tennessee Valley Authority (TVA) and the State of Wyoming signed an agreement that subjects TVA to all the laws, regulations, and taxes the State imposes on private mining companies. *Nuclear Fuel,* Mar. 31, 1980.

[36] In one case, the amount devoted to such payments was 10 percent of the cost of plant construction. Hilliard W. Paige, Daniel S.

The Act also provides for impact payments to units of local government within which a monitored retrievable storage facility is located, and to States and units of local government hosting a Federal interim storage facility. No impact mitigation measures are provided for test and evaluation facilities.

Incentive Measures

Some argue that the benefits provided to States, localities, and Indian tribes asked to host radioactive waste facilities should go beyond simple compensation for impacts, and should instead be set at a level sufficient to provide positive incentives to accept the facilities. Measures to encourage communities or States to accept waste management activities include monetary payments, construction of public facilities, and the tradeoff of siting a waste facility for a pledge to site a desirable project nearby or an undesirable project elsewhere.

Although incentives could lessen opposition to siting, perhaps even making it attractive, they may also have drawbacks. A potential disadvantage of monetary payments, in particular, is that they may appear to prejudice a waste siting decision, possibly increasing suspicion in some communities that they are being bribed to accept something that is unsafe. If incentives are offered to make radioactive waste management activities more acceptable, it may be necessary to tie them to other measures that address health and safety concerns, such as emergency response, and to measures that provide assurances regarding the technical merits of the radioactive waste management program.[38] In addition, there may be a need for explicit upper limits on the amount of incentives that could be provided. Otherwise, depending on the latitude that the beneficiaries of incentive measures are given to negotiate the amounts received, the cost of such measures could become excessive, placing an unfair burden on those who must pay for waste management activities.

NWPA makes no provision for incentive measures beyond compensation for impacts. However, there is no limit placed on the level of tax-equivalent and impact payments for States and Indian tribes affected by repositories, and considerable flexibility is given to the Secretary of Energy in negotiating a package of impact compensation.

Pipman, and Janice E. Owens, *Assessment of National Systems for Obtaining Local Acceptance of Nuclear Waste Management Siting and Routing Activities*, International Energy Associates Limited, IEAL-158, July 1980, "Japan," pp. 9-10.

[37] SPC recommended that impacts of repository development activities should be independently assessed by State, tribal, and local governments as a basis for Federal impact payments. SPC, *Recommendations*, p. 11.

[38] For example, in an interview with OTA on Dec. 11, 1980, members of the New Mexico Governor's Task Force on Radioactive Waste Disposal indicated that Federal compensation to affected States may be appropriate, but only after all the questions about radiological health have been considered.

EQUITY IN SITING WASTE FACILITIES

Measures to address State concerns about the impacts of waste management facilities will not necessarily address their concerns about equity in the siting of those facilities. Measures dealing explicitly with the question of equity may help increase the acceptability of siting decisions. Though State laws banning out-of-State waste probably could be overturned with relative ease,[39] the passage of such laws by a number of States indicates the strength of State concerns about equity in the siting of waste management facilities. Nonnuclear States, in particular, feel keenly the intrinsic unfairness of storing or disposing of the waste of nuclear States. Nuclear States, for their part, are understandably sensitive about bearing more than their perceived fair share of costs.[40]

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[39] Recent court decisions support the conclusion that State or local laws restricting radioactive waste management from outside the State or locality can be preempted. A Louisa County, Va., ban on the storage of spent fuel from facilities outside the county's boundaries was voided by a U.S. District Court judge on Mar. 4, 1983. In issuing that judg-

Concerns about equity have been heightened by proposals for a highly centralized waste management system, using the minimum number of waste facilities technically necessary to store or dispose of waste safely. It may be technically possible for one repository or storage facility with a large annual loading capacity to handle all of the expected disposal or storage needs for decades. This approach might require less initial capital expenditure than an approach involving more or less simultaneous construction of several smaller facilities. Conceivably, only one siting battle would have to be fought for the disposal or storage system, avoiding the additional battles engendered by additional facilities.

From an equity standpoint, however, the centralized approach has important drawbacks. While the meaning of fair distribution differs from person to person, one factor is generally included in equity perceptions: to the extent possible, beneficiaries of actions should bear the accompanying costs. There is disagreement, however, about who are the primary beneficiaries of the activities that have generated commercial high-level radioactive waste. Some consider the benefits of nuclear power to be national in scope because, for example, nuclear power aids energy independence. Others focus on a smaller class of beneficiaries, the direct consumers of electricity generated by nuclear power. Whichever view is taken, use of a minimum number of large facilities for storage and disposal of radioactive waste would make it inevitable that many of the beneficiaries of nuclear power generation would not bear a proportionate share of the impacts of waste management.

Thus one advantage of centralized systems—that it is easier to expand a first facility than to build another one—is a distinct disadvantage in an equity sense, since it favors the concentration of the negative impacts of waste management in a very few areas. Moreover, a system utilizing a single, large storage or disposal facility will probably necessitate a longer transportation network that affects a greater number of States than a system with regional facilities, if those facilities are located near the sources of waste.

Federal policy that takes into account State concerns about equity may be less likely to provoke State opposition. At various times, Federal officials have noted equity considerations and proposed measures to increase equity in siting. For example, DOE's environmental impact statement (EIS) on commercial radioactive waste management considered equity as a social issue and, partly in response to concerns about equity, stated that DOE would consider the feasibility of regional repositories,[41] although no official commitment was made.

NWPA contains two features that relate to equity in siting. First, it encourages interim spent fuel storage at reactor sites and strictly limits Federal interim storage to 1,900 tonnes, to be used only by utilities that are unable to provide their own storage in time. Onsite storage provides assurance that at least some beneficiaries—in this case, utilities and their customers—will bear interim storage costs. It would be difficult for a small number of away-from-reactor facilities, especially if federally owned, to restrict the costs only to the utilities involved. In addition, onsite storage involves less transportation of spent fuel than does away-from-reactor storage; hence, the number of communities affected and potentially the number of transportation accidents would be reduced.

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ment, the judge cited NWPA as clearly giving the Federal Government the authority over storage of radioactive material. He also cited the Federal Government's exclusive authority over radiation safety and over interstate commerce. *The Radioactive Exchange*, vol. 2, Nos. 3 and 4, Mar. 22, 1983, p. 20. Furthermore, on May 2, 1983, the Supreme Court decided not to review lower court decisions that declared unconstitutional laws of the States of Illinois and Washington which imposed restrictions on the transportation and storage of radioactive materials in those States. This action allowed the lower court decisions to stand. *The Radioactive Exchange*, vol. 2, No. 8, May 20, 1983, p. 10.

[40] For example, testimony of former Nevada Governor Mike O'Callaghan before the Subcommittee on Nuclear Regulation, Senate Environment and Public Works Committee, Nov. 14, 1979.

[41] *Management of Commercially Generated Radioactive Waste, Final Environmental Impact Statement*, U.S. Department of Energy, DOE/EIS-0046F, October 1980, vol. 1, p. 3.45.

Second, in response to concerns about the question of regional equity, NWPA requires the development of two geologic repositories.[42] It also specifies that transportation impacts be taken into account in siting the second repository, a stipulation that appears to be intended to encourage location of the second repository closer to the sources of waste generation than the sites now under investigation for the first repository.[43]

While NWPA requires siting and licensing two repositories, it only authorizes construction of the first. The Act does not require operation of the second until 70,000 tonnes of spent fuel or waste have been placed in the first—which could take more than 20 years. Some State officials have suggested that if a regional strategy is adopted, simultaneous regional repository activities might be necessary to assure potential host States that the first repository would not be the only repository. Equity considerations could thus support a commitment to a schedule involving operation of the second repository within a reasonably short time after the first, as provided in the conservative Mission Plan described in chapter 6.

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[42] IRG, for example, recommended siting repositories on a regional basis, as far as the technical considerations would permit. IRG, op. cit., pp. 51-52.

[43] In support of this provision during the debate on NWPA, Senator Slade Gorton (Wash.) stated: "In the case of the State of Washington, it is my opinion that it should be asked to do no more than provide nuclear disposal capacity adequate to dispose of those wastes which are generated within a range of distance in which the transportation risks can be minimized. Other States in other regions of the country should be responsible to provide disposal capacity for nuclear waste generated within similar ranges of those disposal facilities. We should not be planning to move high-level nuclear waste across the continent if we can avoid it. We should not be looking to a State on one side of the continent to provide disposal capacity for waste generated on the other." (*Congressional Record*, Dec. 20, 1982, p. S15667.)

PUBLIC INVOLVEMENT

Public interest in radioactive waste management comes from concerns about its potential hazards and from its possible linkage to the future of nuclear power. The checkered history of radioactive waste management has convinced some members of the public that the hazards may not be sufficiently understood or fully explained by Government officials. Some feel that the promoters of nuclear techology may not be sufficiently conservative about public health and safety. Others are concerned that delays in implementing permanent waste disposal may impair the authorization of new nuclear reactors, thereby jeopardizing the energy security of the country and perhaps their own jobs. As with hazardous waste disposal, many citizens living near a candidate site adopt the attitude "not in my backyard." Through grassroots organizing efforts, some special-interest groups attempt to stymie the waste-siting process and demand an end to the production of more waste, thereby stopping nuclear power. Nuclear waste and radiation are also associated with many negative images, such as nuclear weapons, cancer, and birth defects. It is understandable, therefore, that many members of the public have sought greater access to the decisionmaking process, in the belief that the Government has not made the best decisions in the past.

The call for additional avenues for public participation is usually predicated upon a belief that public acceptability is central to the resolution of a particular societal problem such as radioactive waste management. The fundamental objectives often quoted for public participation in a Government program are:[44]

- *To improve the quality of Government decisions through the solicitation of broad public input and review.* Public scrutiny has improved some Government programs, such as the trans-Alaska pipeline. Participation by the "technical" public through peer review by outside expert groups is obviously valuable in program design and implementation. Because confidence that a geologic repository will perform as desired over millenia must ultimately rest on confidence in the soundness of the underlying scientific analysis, extensive peer review of this analysis at each step can play an important role in assuring the public that radioactive waste will be disposed of safely. General public review is also valuable because technical decisions implicitly involve social values. Public input allows Government officials to discern what the public wants and assists them in formulating technically and politically acceptable policies. Some of the chronic technical, institutional, and political problems that have occurred in the waste management program in the past might have been eliminated or alleviated through wider public scrutiny.

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[44] See, for example, A. Henry Schilling and Stanley M. Nealey, "Public Participation in Nuclear Waste Management," Battelle Human Affairs Research Centers, Seattle, Wash., April 1979.

- *To enhance the legitimacy of and to build support for a Government program.* Once implementation of a program has begun, voluntary compliance or active cooperation by key individuals, firms, and groups is often essential for a program to achieve its goal. If a significant segment of the public believes its concerns are being ignored, it can stop virtually any project by devoting sufficient resources to do so. Making the decision process open to public inspection and responsive to input from responsible parties can result in greater public acceptance and understanding of the decision.
- *To inform and educate the interested public, so that they can act as they deem appropriate.* Effective, intelligent, and meaningful public involvement in Government decisionmaking processes often requires adequate information and education.[45] Members of the public can most appropriately decide on their own how to be involved in Government decisions if they are well-informed about the issues involved in those decisions.

Thus, the purpose of increased public participation is for the Government to reach wise, just, and fair decisions that can be implemented successfully. The implicit hope of proponents of public participation is for the Government to make better decisions in radioactive waste management than it has in the past. Increased public participation, however, does not automatically build public support.[46] Sometimes more information increases fears and concerns, thereby leading to polarization rather than consensus. The desire by some to minimize public participation, e.g., in military programs for waste management, is based on the fear that increased visibility will create increased opposition.

Nonetheless, public involvement can pinpoint problems that need further attention by the Government as well as accelerate the ripening of an issue in order to initiate the settlement process. Ignoring the need for public participation may only postpone problems that appear later in a program's development. While an inadequate technical program cannot be made acceptable solely by public participation, public scrutiny can highlight difficulties that need the application of more Government resources. In controversial issues of high public visibility, such as radioactive waste disposal, Government officials will probably have to accommodate increased demands for sharing of information and even some authority.

Considerable opportunity for public involvement in Federal Government activities is already required by existing law and administrative procedure. The Administrative Procedure Act,[47] for example, requires notice in the *Federal Register* and public hearings for various Federal actions, e.g., rulemakings. The regulatory agencies must hold formal public commenting periods on draft rules, standards, and regulations prior to promulgating final versions. The National Enviromental Policy Act (NEPA) requires the preparation of environmental impact statements that entail public participation opportunities in the notice of intent, public hearings, and commenting process. In a final EIS, Federal officials are required to respond to public comments received on the draft EIS. Regulations promulgated by the Council on Environmental

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[45] IRG stated, "The IRG's own experience with public participation and the recommendations of many citizens appearing before the IRG indicate the urgent need for sustained, effective efforts to inform the public and to provide opportunities for discussion between the public and the Government." IRG, op. cit., p. 96.

[46] A representative of the League of Women Voters observed that "if increasing the likelihood of project completion is an agency's sole rationale for involving the public, the process will certainly fail to reach even that single, limited objective . . . If people sense (accurately) that they are involved only to be sold a particular decision, the seeds for failure are well sown." Susan Wiltshire, "Public Involvement in Nuclear Waste Management Decisions," *Proceedings of the 1982 National Waste Terminal Storage Program Information Meeting,* U.S. Department of Energy, DOE/NWTS-30, December 1982, pp. 214-216.

[47] 5 U.S.C. 551, et seq.

Quality have broadened the opportunities for public review and involvement in NEPA implementation. The legislation that established DOE directed it to encourage and provide for public participation in the development of national energy programs; the DOE Citizen Participation Manual was produced in 1979 as a result. The Office of Management and Budget has required that local communities be informed of Federal Government projects that are likely to affect them. Formal licensing procedures, such as those required by NRC's procedural regulations for high-level waste repositories, offer opportunities for public and State participation through public hearings in the siting and licensing process. The Uranium Mill Tailings Radiation Control Act of 1978 contains provisions for public participation in remedial action programs, as do the rules promulgated by DOT for selecting alternate routes for transport of radioactive waste. In addition, the Freedom of Information Act increases open public access to a broad range of information about Federal activities.

The many available avenues for public participation in Federal programs also include formal and informal mechanisms not required by law. These include:

- public meetings that incorporate presentations by Government officals;
- outside advisory panels and review committees created for various Federal programs;
- library and information services provided by Government agencies;
- submission of unsolicited comments and advice to program managers;
- public surveys and questionnaires for identifying public concerns and opinions; and
- congressional lobbying by various special interest groups to put pressure on executive branch officials.

Federal radioactive waste management programs have, since 1976, provided significant public participation opportunities in the development of national policies and plans.[48] For example, the Carter administration created the Interagency Review Group (IRG) to produce formal policy recommendations for the President in radioactive waste management. According to an IRG staff member:

> The IRG recognized two reasons why obtaining input from interest groups and the public was critically important. First, it believed that its policy recommendations would not be useful or capable of being implemented unless they commanded broad support. Second, it believed that the legitimacy of the outcome and willingness of the public to accept it depended in large measure on the legitimacy of the process itself and on giving the public a chance to participate and be heard. In short, the IRG sought both to accommodate its policies to external reality and to draw relevant interest groups into the process in the hope that because of their involvement, they would be more likely to support the policy outcomes.[49]

Public hearings, meetings with interest groups, and solicitation of public comments on draft documents were used by IRG for public involvement. Approximately 15,000 copies of the draft IRG report were distributed, and comments were actively sought. Some 3,300 written comments were received. The review of the public comments led to the reopening of internal IRG discussions on many of the difficult policy questions. The revised IRG report published in March 1979 contained the text of the draft report, the drafting committee's summary of the public comment on each section of the draft, and an IRG response to these comments. These responses frequently involved extensions and revisions of findings contained in the draft report.[50] President Carter adopted many of the IRG recommendations in his policy statement of February 12, 1980, and stated that:

> . . . it is essential that all aspects of the waste management program be conducted with the fullest possible disclosure to and participation by the public and the technical community.[51]

In addition to public participation in national policy discussions, various segments of the public have undertaken activities at specific project sites. The proposed Waste Isolation Pilot Plant has for several years elicited intense interest, both in support and opposition, from groups in New Mexico. Other potential host States for a repository have had contacts and public information meetings with Federal officials over a period of years. Since attempting to site a repository in Kansas in the early 1970's, DOE has increased contacts with State and local officials and the public at proposed project sites, apparently recognizing that "a Federal agency disregards at its peril the potential power of State and local officials whose opinions reflect the consensus of their constituency on matters of health and safety."[52]

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[48] See Schilling and Nealey, op. cit.

[49] Greenwood, op. cit., p. 22.

[50] Ibid., pp. 22-23.

[51] "Fact Sheet: The President's Program on Radioactive Waste Management," Office of the White House Press Secretary, Feb. 12, 1980, p. 10.

Congress, in passing NWPA, found that "State and public participation in the planning and development of repositories is essential in order to promote public confidence in the safety of disposal of . . . waste and spent fuel."[53] To accomplish this, NWPA specifies a detailed process for State involvement and for public hearings and review of environmental analyses prepared by DOE at various stages of the siting process.

Review of past Federal efforts at public participation in radioactive waste management activities, and of critiques of those efforts by non-Federal observers,[54] suggests three steps that could increase public confidence in DOE's public involvement program:

1. **Commit additional resources to public involvement.**

Because of the importance of public acceptability of DOE waste management activities, planning and implementation of public involvement programs require the same degree of care and attention as technical programs.[55] The need for improvements in the program for public involvement in repository development activities was the subject of many public comments on DOE's draft guidelines for repository site selection.[56] While DOE strongly endorses the concept of public participation at the State and local levels,[57] it may be necessary to dedicate additional resources—in terms of staff, funds, and management attention—to that task.

As noted in chapter 7, questions were raised prior to passage of NWPA about the relative weakness of the DOE waste program staff in the area of the nontechnical aspects of waste management. The increased level of interaction with the States and public required by the Act will place even greater demands on DOE in that area. Thus creation of an adequately staffed and financed program group devoted solely to DOE relations with non-Federal actors, including the general public, as suggested in chapter 7, could increase confidence that public involvement will receive a level of attention commensurate with its importance to the success of the program. The newly established outreach division within the Office of Civilian Radioactive Waste Management may accomplish this.

Mechanisms for some public participation in Federal radioactive waste programs surely will continue to be provided, if only because of the existing legal and procedural requirements. However, some outside groups that have studied the Federal Government's public participation efforts in the area of radioactive waste management have found those efforts wanting in some way, either directly—

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[52] Richard G. Hewlitt, "Federal Policy for the Disposal of Highly Radioactive Waste from Commercial Nuclear Power: A Historical Analysis," (Washington, D.C.: U.S. Department of Energy, Mar. 9, 1978).

[53] Public Law 97-425, sec. 111(a)(6), 96 Stat. 2207, 42 U.S.C. 10131.

[54] See, for example, "Public Participation in Developing National Plans for Radioactive Waste Management: Summary Report of the Second Keystone Conference on Public Participation in Radioactive Waste Management Decision Making," (Keystone, Colo.: Keystone Center for Continuing Education, October 1980). The conference concluded, "If adequate plans for public participation are not prepared soon and carefully executed, Federal-State relationships could be harmed; DOE's credibility could be reduced further; and progress in implementing (President Carter's) new radioactive waste program could become more difficult." Letter to Stuart Eizenstat from Robert Craig and Terry Lash, July 15, 1980, p. 3, appended to the conference report.

[55] This point is emphasized in a letter from SPC to President Carter, which stated: "Public participation in waste management planning and programs is sufficiently important to deserve the same quality of thought, commitment, and implementation as technical programs. This requires a clear definition of goals and objectives; a detailed framework of operating policies, procedures, and/or regulations; and management cognizance, control, evaluation and improvement." The text of the letter is found in app. E of SPC, *Recommendations*. See also *Nuclear Waste Management Process Review Forum: Final Report* (Palo Alto, Calif.: RESOLVE Center for Environmental Conflict Resolution, June 1980), pp. 36-37.

[56] U.S. Department of Energy, *Responses to Public Comments on the Proposed General Guidelines for Recommendation of Sites for Nuclear Waste Repositories*, Draft, May 27, 1983, vol. 1, pp. IV-10—IV-12.

[57] Ibid., p. IV-12.

through explicit criticism—or indirectly—through detailed recommendations for change. For example, the Keystone Center's conference on public participation in July 1980 concluded that:

> Involvement of the public and non-Federal jurisdictions in making decisions about management and disposal of radioactive wastes is important for gaining needed improvements in the overall Federal program, enhancing the credibility of Federal agencies' programs (when warranted), and educating the public about those programs and the technology of waste disposal. *Current Federal plans for obtaining public participation need substantial improvements to achieve this objective* (emphasis added).[58]

Such criticisms suggest that additional efforts are needed.

2. Include an explicit public involvement plan in the Mission Plan.

DOE agrees with the need for involvement by both the lay and technical publics in the waste management program.[59] However, it has yet to publish explicit policies or a long-term plan showing how such involvement is to be carried out and how the results are to be used in the decision process.[60] As noted in chapter 5, the broad distrust of the Federal waste management program that developed as a result of past experiences means that a high degree of explicitness about and commitment to policies and programs is needed to rebuild credibility. Thus, confidence that an adequate public involvement program will be carried out could be enhanced by including a detailed public involvement plan in the Mission Plan.[61] This plan should make clear whose comments will be sought, where the interaction will take place, how the comments will be used, and how decisions will be made. It should also include explicit provisions for an objective public information program[62] and for a systematic technical peer review process.[63] Confidence would be further increased if this plan were accompanied by a long-term budget for carrying it out, to ensure that the costs of public involvement are explicitly included in the estimates of overall program costs so that adequate resources can be made available from the Nuclear Waste Fund.

3. Use the Mission Plan as a focus for public involvement.

A frequent theme of recommendations for public involvement activities is the development of a national radioactive waste management plan as the focal point for such activities.[64] An attempt was made by DOE during the Carter administration to develop a National Plan for Radioactive Waste Management. The administration circulated the fourth working draft of the plan to State governments and Congress for comment before producing a revised draft for formal public review. The intention was to produce a final version after obtaining public comments and then to update the plan biennially by repeating the process. It was hoped that the preparation of a National Plan might then become a useful vehicle for improving coordination among Federal agencies, incorporating comments from States and Indian tribes, and eliciting public participation. The Reagan administration received the comments on the draft plan from the States and Congress, but it did not proceed with the development of a document for review by the general public.

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[58] Keystone Center, "Public Participation," p. iv.

[59] Department of Energy, *Responses*, p. IV-12 and IV-27.

[60] An example of a formal Federal agency policy for public participation can be found in the Environmental Protection Agency's policy published in the *Federal Register*, vol. 46, No. 12, January 19, 1981, pp. 5736-5746.

[61] The value of explicit, detailed plans for public involvement is identified in the SPC letter to President Carter, op. cit.; in the *Final Report* of the RESOLVE forum, pp. 36-37, and in the report of the Keystone Center, "Public Participation in Developing National Plans," p. iv.

[62] The importance of a public information program has been emphasized by a representative of the government of the State of Mississippi: "The only means through which this nation is going to effectively solve the problem of radioactive waste disposal is through the process of gaining a public confidence that the Federal, State and local governments and the public sector are satisfied that the waste disposal program is credible and is designed to absolutely assure the public health and safety and the environmental quality. There is only one mechanism by which such a program can be successful. That mechanism is a comprehensive, completely objective public information program." Testimony of Ronald Forsythe, Mississippi Energy and Transportation Board, before the Subcommittee on Energy and Environment of the House Committee on Interior and Insular Affairs, May 26, 1983.

[63] Additional efforts may be needed in the area of peer review. Addressing this subject in a 1983 report, a National Research Council panel concluded that DOE "should institute a more deliberate overall technical review of its program on geologic disposal. This technical review should be done on a continuing and extended basis, with full technical input representing the technical breadth of the program . . ." National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes* (Washington, D.C.: National Academy Press, 1983), p. 15.

[64] For example, the Keystone conference on public participation recommended, "A National Plan for the management of radioactive wastes should be prepared through an extended process involving the knowledgeable and concerned segments of the public, and the appropriate officials of State, tribal, and local governments." Keystone Center, "Public Participation," p. iv. Similarly, SPC concluded, "A National Plan, which would be updated periodically, is vital to improve coordination among the Federal agencies, to build and maintain the Federal/State/tribal partnership, and to involve the public in the decision making process." It recommended that the National Plan process be carried forward. SPC, *Recommendations*, pp. 28-29.

As discussed in chapter 5, NWPA requires DOE to prepare a comprehensive Mission Plan for the waste management program. Chapter 6 showed that the choices to be made in the Mission Plan will involve many decisions about the waste management program that will have significant implications for many affected parties—e.g., the utilities and their ratepayers, the communities affected by waste transportation, and so on. For example, the timing of operation of the second respository could greatly influence the number of States affected by waste transportation, while the planned full-scale loading capacity of the repository system will determine the level of impacts of waste transportation and the length of time that utilities will have to care for spent fuel stored at reactors. While NWPA does not explicitly require DOE to provide for broad public involvement in preparation of the Mission Plan, such involvement could be a useful means of developing broad support for the Plan by those affected by the choices made in it, and in fact may be a necessary step for achieving that objective.[65]

DOE widely circulated a preliminary draft of the Mission Plan for comments, which were used in preparing the formal draft required by NWPA. As suggested in chapter 7, a process of extensive public and technical review of this formal draft, and of any subsequent revisions of the Plan after it has been submitted to Congress as required by the Act, could help develop broad national understanding of and agreement about the high-level waste management program.

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[65] SPC stated that "public participation must be incorporated to produce a 'true National Plan.' " Letter to President Carter from Governor Richard Riley, Chairman of the State Planning Council, Jan. 13, 1981, p. 2, contained in the appendixes to the SPC *Interim Report*, Feb. 24, 1981. The Keystone conference on public participation also agreed that public participation in development of a National Plan "is needed if the administration's plans are to be widely accepted and workable." Letter to Stuart Eizenstat from Robert Craig and Terry Lash, July 15, 1980, p. 2, appended to October 1980 report of the conference.

Appendixes

Appendix A-1

Radioactive Waste Management Policymaking*

Acknowledgments

In preparing this paper, the author accumulated a number of debts that he can only hope to partially repay with these words of acknowledgment. William Barnard of the Office of Technology Assessment was a constant source of encouragement and support as this effort, initially planned to be of 2 months duration, stretched into many months. He also carefully read the first draft and offered helpful criticisms. David Stewart of the U.S. Geological Survey provided much information as well as useful suggestions for improving the first draft. Alex Perge of the Department of Energy (DOE) also commented on the first version of the paper and pointed out some factual errors. Several unknown reviewers from DOE and the Nuclear Regulatory Commission (NRC) helped improve the accuracy of appendix A-2.

In addition to David Stewart, the author greatly benefited from detailed internal decision memoranda obtained from the Office of Science and Technology Policy and from NRC. The Office of the Historian at DOE was extremely helpful in providing decision memoranda for the period prior to 1975. Sheldon Meyers, Director of DOE's Office of Nuclear Waste Management, and his staff also provided assistance. However, they were unable to find or to produce some key decision papers for the post-1975 period. That unfortunately made this analysis less complete than it might otherwise had been.

Marcia Picket did an admirable job in typing the drafts and the final product.

Despite all these efforts to facilitate the work and to improve it, errors undoubtedly remain. For this I take full responsibility.

The Imperative

The philosopher Hans Jonas poses the central ethical issue of our new technological age as he observes that the days have passed when:

> The good and evil about which action had to care lay close to the act, either in the praxis itself or in its immediate reach, and were not a matter for remote planning . . . Proper conduct had its immediate criteria and almost immediate consummation. The long run consequences beyond were left to chance, fate or providence. Ethics, accordingly, was of the here and now, of occasions as they arise between men, of the recurrent, typical situations of private and public life.[1]

Instead, suggests Jonas,

> [T]his sphere is overshadowed by a growing realm of collective action where doer, deed, and effect are no longer the same as they were in the proximate sphere, and which by the enormity of its [technology's] powers forces upon ethics a new dimension of responsibility never dreamt of before.[2]

Advocating a new categorical imperative—"In your present choices, include the future wholeness of Man among the objects of your will"—Jonas recapitulates a theme which underlay the intent of those managing radioactive waste from the time they were first produced, nearly 2 score years ago.

Introduction

Radioactive waste management is a problem that is not quite like most others that have come within the Government's purview. There are technical and institutional uncertainties associated with this problem; some of them unknown and possibly large; some of those uncertainties are, in principle, unresolvable. The cost of error may be high, and the time constant of feedback about error is great. No jurisdiction is enthusiastic about locating waste management facilities within its confines; yet if all decline, a pressing national need will not be met, thus opening the way for a repeat of the "tragedy of the commons."

This paper is about radioactive waste management problem-solving. It examines how the Federal Government responded to an issue of high complexity, potentially large risk, and intense political controversy. Eight dimensions of waste management problem-solving are considered:

- the determination of what constitutes waste;
- the storage of radioactive waste;
- the role of the earth sciences in designing waste disposal facilities;
- the development of strategies for searching for disposal sites;
- the use of engineered barriers in the design of waste disposal facilities;
- the determination of acceptable levels of risk in disposing of radioactive waste;
- the interaction between the States and the Federal Government in the area of waste management; and
- the relationship between waste management and the production of nuclear power.

For each of these elements, two questions are raised: How did a particular aspect come to be recognized as part of the "problem?" How did the understanding of the eight problem elements evolve over time? Once those questions have been considered, we ask a third one: How did conceptualizations of the problem and decisions taken at one point influence problem-solving during subsequent periods of time? We shall try to learn the reasons why policymaking was sometimes quite successful and why it was sometimes not. By doing that we hope to provide insights into designing and implementing programs that might be useful guides for the future.

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*The material in this appendix was prepared for OTA by Daniel Metlay of the University of Indiana under contract No. 033-2690.0, June 1981.

[1] Hans Jonas, "Technology and Responsibility: Reflections on the New Task of Ethics, *Social Research 40*, spring 1973, pp. 35-36.

[2] Ibid., p. 38.

Before we can proceed with that analysis, the stage must be set, a foundation must be laid. For those unfamiliar with the details and history of radioactive waste management, four chronologies have been prepared and are included in appendix A-2. The chronologies describe, in turn, events dealing with waste storage, events dealing with waste disposal, events dealing with the regulation of radioactive waste, and events affecting organizational structure and responsibility for waste management. In addition, a "time line" has also been prepared and appended which shows the sequence of some of the major events in waste management history. Of more general interest, however, is a discussion of the **context** within which waste management problem-solving occurred. The evolution of waste management policymaking can only be partially understood without reference to that context. It is to that second component of the foundation that we now turn before addressing the eight specific areas of the problem.

The Context of the Policymaking Process

Richard Cyert and James March correctly observed that complexity and uncertainty generate dilemmas about how to act. According to them, decisionmakers in organizations appear to resolve those dilemmas through the use of a particular strategy:

> [Policymakers] make decisions by solving a series of problems; each problem is solved as it arises; the organization then waits for another problem to appear. Where decisions within the [organization] do not naturally fall into such a sequence, they are modified to do so.[3]

Thus, policymakers give pressing problems priority; what had to be done yesterday draws their first attention today. Problems which can wait, wait.

A high degree of complexity and a substantial amount of uncertainty affect policymakers' behavior in other ways as well. Decisionmakers tread carefully; they cautiously implement policies that are minimally disruptive; they monitor the consequences of their actions and evaluate whether those consequences are satisfactory or unsatisfactory. When faced with outcomes that are not acceptable, they search in the neighborhood of the existing policy to find alternatives. To simplify the complexity they confront, policymakers generally ignore factors that appear only marginally related to the core of their efforts; sometimes they even ignore factors that are substantially related but which are, for any number of reasons, intractable or elusive.

The evidence is strong that the policymaking process for the back-end of the nuclear fuel cycle followed the patterns of organizational behavior just described, at least during the three decades prior to 1975. The Atomic Energy Commission (AEC), the developer and the regulator of the nuclear power technology, deferred the search for long-term solutions to the problem of waste management. When the problem could be finessed, it was; when it could not be, waste management was dealt with in ad hoc ways. Such responses are hardly unreasonable. Indeed, given the limitations inherent in the exercise of cognitive power by individuals, as well as more mundane but important constraints such as budget ceilings, they may represent the best strategy available. Nonetheless, those responses may prove ultimately to be inadequate and insufficient; their employment may lead policymakers into situations from which they cannot easily or gracefully escape.[4]

What factors facilitated this fragmentation of nuclear power policy and the subsequent minor emphasis given to waste management? First, attitudes held by the AEC Commissioners and operating personnel played a role. The Commissioners never got personally excited about the problems of waste management. In the history of AEC, there was only one Commissioner, Clarence Larson, who took a major interest in waste management. But even he never championed the area's needs in the same manner that James Ramney pushed reactor development or Glenn Seaborg pushed physical research. For most of the Commissioners, waste was unpleasant, unglamorous, and low priority.

Evidence for this proposition comes from interviews with key participants involved in the decisionmaking processes that took place prior to 1975. One person who dealt with the Commissioners every day described the obstacles he encountered:

> To get them interested was very difficult. There was not a lot of glory in waste. No one wanted to be a champion of waste. Milt Shaw and I went to get the Kansas Governor's approval [for the Lyons repository] but not one Commissioner would go to do it. No one wanted to get tagged as having waste being his bag . . . One division or another would develop things about waste man-

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[3] Richard Cyert and James March, *A Behavioral Theory of the Firm* (Englewood Cliffs, N.J.: Prentice-Hall, 1963), p. 3.

[4] See, Daniel Metlay, *Error Correction in Bureaucracy*, unpublished Ph. D. dissertation, University of California, 1978, especially chs. 1 and 5.

> agement within the staff; the Commission tolerated it, but they were really interested in reactors . . . I'd have a hard time finding someone on the Commission who thought he was responsible for waste.[5]

A program director dealing with waste management during this period offered a similar view: "One of the problems the Commission had for years was that the emphasis was on the development of reactors and to hell with anything to feed or service reactors. That was because the sexy part of this industry was the damned reactor."[6] A former Commissioner summed up how one of his colleagues treated the issue of waste management by recalling that "every time anyone mentioned waste to X, [he] would make a face, turn up [his] nose, and move on to another subject."[7]

Nor could the cause of waste management be sustained through the skillful use of internal politics by personnel at lower levels. For them to pursue the issue intensely hardly made much sense. Grand careers were made in reactor development where the organization's resources were committed, not in waste disposal. Moreover, waste management also seemed to lack the intellectual challenges of reactor research or high energy physics.

A second influence, more subtle but extremely pervasive, which led policymakers to place a low priority on waste management and which reduced their sensitivity to potential errors in their actions was a sense of technological optimism. By technological optimism we mean a systematic perception on the part of scientific and technical professionals that solutions to problems can be crafted through the straightforward administration of readily available technologies. It is, in Leon Lindberg's words, "an overwhelming faith in progress . . . that admits of few limitations to the ability of scientific knowledge to solve problems."[8] Obviously, much of this optimism is justified by past experience. Scientists and engineers have solved a wide range of problems and have fundamentally altered modern society. However, should this faith be too rigidly held or if it is misplaced, then serious distortions can arise. In particular, there is a tendency among those gripped by technological optimism to discount substantially aspects of problemsolving which are not technological.[9] This proclivity can lead them to misspecify and misconstrue the character of the problem and to adopt policies that prove to be inadequate. The evolution of waste management policy provides a striking illustration of both the sense of technological optimism and its often accompanying tendency to discount the nontechnical components of problemsolving.

For at least 25 years, the nuclear developers maintained that radioactive waste management was an easily solved problem; by extension, it was also one that could be disaggregated and ignored until a system was actually required. A plethora of examples document the policymakers' sense of technological optimism. We cite just a few. One manager in the Division of Reactor Development and Technology testified before the Joint Committee on Atomic Energy (JCAE) in 1959:

> Although one has to be careful to distinguish between aspiration, reality, and speculation, it is my strong feeling that the development program has thus far found solutions to some of the waste problems and at least indications of solutions to others.[10]

Even the most visible failure in waste management history, the Lyons project, was seen as technically feasible by program personnel. The Oak Ridge engineer in charge of that effort was asked whether the laboratory could have handled the problems which arose in Kansas. He replied, "Of course, it was technologically possible."[11] One executive in charge of waste management development remarked: "The easiest part of the reactor business is the waste management portion. I can't believe that it has ended up as it has."[12] The Director of the Division of Waste Management reflected official attitudes when he told the American Nuclear Society: "We do have today, in the retrievable surface storage facility, the answers needed for safe management of commercial high-level radioactive waste."[13]

In sum, one gets a strong impression from reading the public record and from talking with former AEC personnel that, if they had just been given enough money and had been left alone, they could and would have solved the "problem" expeditiously and to virtually everyone's satisfaction.

Interestingly, this position was held despite repeated technical setbacks in a number of efforts to manage the byproducts of nuclear fission. The storage of military wastes at Hanford has been plagued with numerous problems. Tanks expected to hold the liquid waste for 50 to 100 years have corroded and leaked after less than 25.[14] Although the waste stored at the Savannah River facility have not leaked into the environment, plans to dispose of the material in the bedrock underlying the plant have not been consummated in part because of potential technical difficulties.[15] The legacy of the Nuclear Fuel Service operation, 640,000 gallons of waste in upper New York State, will cost nearly a half billion dollars to dispose of. The attempt to build a repository at Lyons failed in part because it was too hastily conceived and designed. Low-level wastes have migrated from their burial sites at Maxey Flats, Ky., despite repeated predictions that such movements were physically impossible.[16]

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[5] Confidential interview with author, 1975.

[6] Confidential interview with author, 1976.

[7] Confidential interview with author, 1975.

[8] Leon Lindberg, "Energy Politics and the Politics of Economic Development," 1976, p. 29.

[9] See, Ida Hoos, "The Credibility Issue," in W. P. Bishop, et al., *Essays on Issues Relevant to the Regulation of Radioactive Waste Management,* NUREG-0412, U.S. Nuclear Regulatory Commission, 1978, for a good discussion of this point.

[10] U.S. Congress, Joint Committee on Atomic Energy, hearings, *Industrial Radioactive Waste Disposal,* 86th Cong., 1st sess. (Washington, D.C.: U.S. Government Printing Office, 1959), pp. 992-993.

[11] Confidential interview with author, 1975.

[12] Ibid.

[13] Speech by Frank Pittman to the American Nuclear Society, Nov. 16, 1972. Reprinted in Atomic Energy Commission Press Release S-18-72, p. 2.

[14] See, *Environmental Impact Statement, Waste Management Operations, Hanford Reservation, Richland, Washington,* WASH-1538, U.S. Atomic Energy Commission, 1974.

Moreover, the sense of technological optimism was maintained despite the fact that past technological approaches to what must be regarded as a long-term problem have proven to be only temporary stopgaps. The experience at Hanford illustrates that point. To cope with the leakage from the corroding tanks, a decision was made in 1965 to evaporate completely the waste solutions; the resulting salt cake not only would not leak, but also it would seal up any holes in the tank. Yet, many knowledgeable people agree with the Natural Resources Defense Council's observation that:

> Eliminating the excess liquid has to a great extent also ended [the government's] ability to remove the waste from the tanks since as damp solids the waste can no longer be pumped hydraulically out of the tanks. Moreover, liquids cannot be reintroduced in too many of the tanks to resuspend the waste since to do so would almost certainly result in substantial leaks to the ground.[17]

While the alternative of mining the waste out does exist, that technique is beset with a number of difficulties: a remote control system for mining would have to be developed; efforts would have to be made to reduce airborne releases; and the material is difficult to deal with physically: thus, the record suggests that past technical efforts have at least occasionally complicated matters for the present and have engendered problems for the future.

No force foreordained this phenomenon of technological optimism. Rather it was something that appears to have evolved and to have been institutionalized. Indeed, as early as 1955, AEC had not become overly sanguine. For instance, one individual from the Division of Reactor Development and Technology told the first meeting of the National Academy of Science's (NAS) Advisory Committee on Waste Disposal:

> To some extent because of our geographically isolated locations (such as Hanford), it has been possible to sweep the problem under the rug, so to speak. But those of us who are close to it are convinced we must face up to the fact that we are confronted with a real problem . . . Looking backward we know of the mistakes that many industries made in assuming that the disposal of waste was simply a back-door problem that any one could handle.[18]

At the same time, his colleague, who 4 years later, would become so optimistic in testifying before the JCAE, noted: "I certainly hope I can disabuse you of the idea that we have any solution that will solve the problems of waste disposal."[19] Yet, if that NAS study began on a note of caution, it ultimately provided the major support for the technological optimism that developed in the agency. Although the writers of the NAS report were careful to note the need for further research, they stated categorically that "the committee is convinced that radioactive waste can be disposed of safely in a variety of ways and in a large number of sites in the United States."[20] Further, they stated that "disposal in salt was the most promising method for the near future."[21] The consequences of such judgments were great. As someone who has been in the waste management program for a number of years put it, "The NAS report did instill a sense of complacency in the minds of the people dealing with waste management. Because of it, we felt that a solution would be available whenever we needed it."[22]

The Joint Committee itself also played an important role in institutionalizing the sense of technological optimism. In extensive hearings held in 1959, JCAE heard one expert after another from AEC, from the national laboratories, from academia, and from industry testify that a technological solution to the waste management problem was possible.[23] Once that technological optimism received the imprimatur of the Joint Committee, JCAE promptly dropped the subject and, for all practical purposes, never returned to it for another 16 years.

The cumulative impact of the way the NAS report was interpreted and the Joint Committee hearings was to legitimize a certain perspective. An illusion of certainty was created where, in reality, it did not exist. Over the years, the sense of technological optimism embedded itself in the attitudes and thoughts of important agency policymakers. It became, in a sense, an official doctrine at AEC. There is no evidence that its validity was ever seriously questioned until the mid-1970's. This optimism facilitated fragmentation by lulling policymakers; agency personnel never fully recognized that they might create in a sequential, incremental fashion an elaborate technological structure, civilian nuclear power, only to find that the last pieces could not be made to fit. The difficulties of integrating the whole were systematically underestimated.

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[15] *Alternative Processes for Managing Existing Commercial High-Level Radioactive Wastes*, NUREG-0043, U.S. Nuclear Regulatory Commission, 1976, p. 12.

[16] See, *Improvements Needed in the Land Disposal of Radioactive Wastes—A Problem of Centuries*, RED-76-54 (Washington, D.C.: U.S. Congress, General Accounting Office, 1976).

[17] Natural Resources Defense Council, "Memorandum and Points of Authorities in Support of the NRC Licensing of the ERDA's High-Level Waste Storage Facilities Under the Energy Reorganization Act of 1974," p. 18.

[18] National Academy of Sciences/National Research Council, *The Disposal of Radioactive Waste on Land*, 1957, pp. 16-17.

[19] Ibid., p. 34.

[20] Ibid., p. 3.

[21] Ibid., p. 6.

[22] Confidential interview with author, 1974.

[23] Ibid.

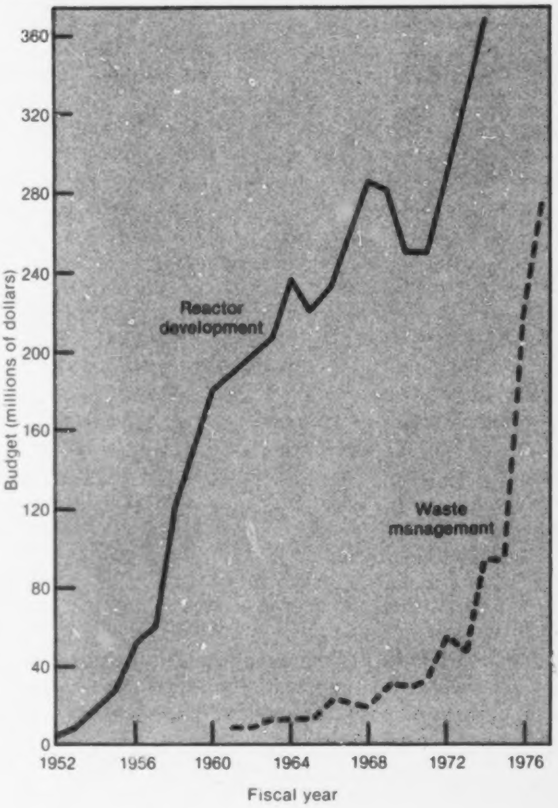
Furthermore, it seems likely that this sense of technological optimism influenced the manner in which decisionmakers conceptualized the issue of waste management. In particular, the lack of attention given to the nontechnical dimensions of policy prior to the mid-1970's may have resulted from a belief that the problem was so readily technically solvable. In such a case, it is understandable that AEC's managers came to view the technology as virtually self-implementing. Only within the last 6 or 7 years has the recognition grown that the nontechnical or institutional aspects of waste management need to be addressed as thoroughly and intensively as the technical ones.[24]

Thus, during the formative years of waste management policymaking, 1945 to 1975, the issue was never given a very high priority by the AEC leadership. Waste was unglamorous; the management of it was not a pressing problem and could therefore be postponed; such a postponement hardly seemed ill-advised at the time because a firm belief prevailed in the nuclear power community that once a need arose, the problem would yield to some readily envisioned, self-implementing technical solution.

The consequences of this state of affairs were twofold. First, budgetary commitments for waste management, the program's staff of life, were minuscule, particularly when compared to funds expended for reactor development. (See fig. A-1 and also table A-1 which detail the allocations for waste management up to the present time.) Those low budgets severely constrained problemsolving as personnel were forced to make do. Second, the years of relative neglect made it harder to respond to rapidly growing external concerns about the adequacy of the waste management program. The organizational and technical infrastructure had not been well established prior to the mid-1970's. As a result, AEC and its successors found themselves in a constant struggle to catch up. When the program appeared to falter, its credibility was challenged. That, in turn, created a situation in which efforts to find solutions were undermined.

In describing the context of policymaking we refrain from critically judging the choices made, even though in retrospect some of those decisions proved to be unfortunate. We do so—and suggest that others do so as well—because, at the time the choices were made, they appeared at least reasonable and, perhaps, given the constraints at work, the most appropriate possible. Thus, while one can properly be concerned about the lack of progress in waste management, one ought not to denigrate those—at all levels—who worked this problem in the past.

Figure A-1.—Expenditure for Reactor Development Compared With Expenditures for Waste Management



Having established the context of policymaking that prevailed up until 1975, we must note that it has changed dramatically over the last half decade. Whereas AEC did not even have a separate organizational structure with its own budget responsible for waste management prior to 1972, now DOE has an Office of Nuclear Waste Management headed by the Deputy Assistant Secretary. Funding for commercial waste management is now over 100 times greater than it was a decade ago. During the Carter administration top officials at DOE maintained that, aside from the strategic petroleum reserve, waste management had captured highest priority. And while decisionmakers over the last 5 years still strongly believe that managing radioactive waste is not

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[24] See, for instance, W. P. Bishop, et al., *Proposed Goals for Radioactive Waste Management*, NUREG-0300, U.S. Nuclear Regulatory Commission, 1978, and *Proceedings of Conference on Public Policy Issues in Nuclear Waste Management*, 1976.

Table A-1.—Waste Management Costs
(dollars in thousands)

Fiscal year	Commercial	Defense
1960 and prior		$ 125,772
1961		8,573
1962		8,940
1963		8,972
1964		11,702
1965		9,492
1966		14,953
1967		17,725
1968		21,020
1969		26,421
1970		27,526
1971		32,017
1972	$ 1,704	44,653
1973	3,750	44,570
1974	6,215	54,998
1975	10,263	83,521
1976 and TQ	16,632	141,203
1977	67,087	162,969
1978	123,236	234,362
1979	179,753	296,899
1980	207,192	313,864
1981	256,343	336,628
1982	317,473	392,000
Total	$1,189,648	$2,418,776

a difficult technical problem, their current optimism has not led them to discount the other dimensions of policy and, perhaps more significantly, appears to be founded on a firmer technical base.

As the reader digests the next sections dealing with the substance of problem-solving, he should keep in mind what the context of decisionmaking was and how that context influenced the action taken.

Defining Radioactive Waste

Radioactive waste comes in a variety of forms; they include uranium mill tailings, low-level waste derived from industrial, institutional, power generating, and military sources, and waste derived from the decontamination and decommissioning of nuclear facilities. While all those forms create some health hazard and therefore must be managed with care, this paper shall concentrate almost exclusively on two other types: high-level and transuranic contaminated waste.

During the early years of the nuclear endeavor, prior to 1970, only low- and high-level waste were distinguished; the former variety had to be kept strictly isolated and contained while the latter could be placed into the environment under conditions of lower constraint. More precisely, AEC in 1957 defined high-level waste to refer to material which "emitted radiation so strong as to materially reduce the time a person can be near the radiating body."[25] In practice, that meant that a release of two or more roentgens per hour arbitrarily qualified material to be classified as high-level waste. Ten years later, that definition was refined to mean material "which, by virtue of its radio-nuclear concentration, half life, and biological significance, requires perpetual isolation from the biosphere."[26]

Some material, such as the byproducts of reprocessing military fuel and the postfission products of commercial power reactors, clearly falls under these radiological definitions of high-level waste. Classifying other material, however, is somewhat more complicated. For instance, material contaminated with transuranic elements, transuranic waste, initially was interred, along with low-level waste, in shallow land burial sites. In the late 1960's, AEC decided to halt that practice and segregate its own transuranic waste for ultimate transfer to and disposal in a geologic repository. In 1974, the agency proposed that commercial waste possessing transuranic activity of greater than 10 nanocuries per gram be treated the same as commission-generated transuranic material.[27] Although that regulation was never adopted and thus no formal definition of transuranic waste is available, there seems to be a fair amount of agreement that transuranic waste, however ultimately defined, will eventually be disposed of in a manner similar to that of high-level waste. The Nuclear Regulatory Commission (NRC) is currently carrying out a study to determine whether other radionuclides, hitherto treated as low-level wastes, should, like transuranic waste, become subject to more stringent management controls.[28]

The very idea of waste connotes something that is valueless. The military high-level waste conforms as readily to this ordinary language meaning of the term as it does to the radiological definition. The material that emerges from a reprocessing plant at the Hanford or Savannah River facilities is economically worthless. The situation, however, with regard to the postfission products of nuclear reactors is somewhat more complex and contentious.

From the earliest days of AEC's reactor development program, the operating assumption was that commercial spent fuel would be reprocessed and its residual uranium and plutonium recycled as fuel. As the Director of Reactor Development wrote Commissioner Libby in 1957, employing this technological alternative would

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[25] "Handling and Disposal of Radioactive Waste," AEC 180/6, June 14, 1957, p. 10.

[26] Minutes of Atomic Energy Commission Meeting 2373, June 3, 1969, p. 13.

[27] See, *Management of Commercial High Level and Transuranium-Contaminated Radioactive Waste,* Draft EIS, WASH-1539, U.S. Atomic Energy Commission, Washington, D.C., 1974, pp. 2.4-1—2.4-17.

[28] See, *A Classification System for Radioactive Waste Disposal—What Waste Goes Where?* NUREG-0456, U.S. Nuclear Regulatory Commission, Washington, D.C., 1978.

"increase utilization of uranium resources and lower fuel costs."[29] (It would also provide the not inconsiderable benefit of facilitating the sale of U.S. reactors abroad.) High-level waste then became whatever was left after reprocessing and recycle. Indeed, the first formal definition adopted by AEC in 1970 held that commercial high-level wastes were "those aqueous wastes resulting from the operation of the first cycle solvent extraction system, or equivalent and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels."[30]

Given the view that reprocessing would be economically advantageous, that definition seemed quite consistent with the ordinary language connotations of the term waste. Within the next 5 years, however, the logic behind AEC's 1970 definition of high-level waste came under challenge. For the ordinary language connotations of waste as something valueless did not seem to apply to reprocessed commercial material alone.

The definitional dilemmas arose because earlier assumptions about the costs of reprocessing no longer seemed to hold. The first reprocessing plant, operated by Nuclear Fuel Services, initially charged a fee that was substantially lower than what the next generation of facilities would have to impose.[31] The increase was believed to be so great that arguments were advanced suggesting that reprocessing might not be economically advantageous at all. Robert Fri, Deputy Administrator of the Energy Research and Development Administration (ERDA), informed President Ford that for the United States, "the economics of the [reprocessing] technology are uncertain, **and even if favorable,** would produce only about a 2-percent reduction in the cost of generating [nuclear] electricity"[32] (emphasis added). Thus, the plutonium and uranium components, to which value had been attributed, might not, after all, be valuable.

The economics of reprocessing were a major element considered in the plutonium recycle rulemaking hearings Generic Environmental Statement on Mixed Oxide Fuel (GESMO) conducted by NRC. The Commission's staff, somewhat more cautious than Fri, predicted a discounted benefit of $3.2 billion over a quarter century for a reprocessing/recycle option compared to the "throw-away" fuel cycle.[33] This is an 8 percent fuel cost advantage, but less than a 1 percent advantage in total electrical costs. Obviously, substantial uncertainties are associated with those predictions. But what is significant is that the logic for defining high-level radioactive commercial waste was seriously and officially undermined; unreprocessed spent fuel rods could now satisfy both the ordinary language and radiological definitions of waste.

The GESMO analysis is notable in an ironic sense as well. Whereas the definition of waste was initially a byproduct of an intuitive commitment to reprocessing and recycling, now reprocessing and recycling were being advocated, in large degree, on the basis of waste management considerations: 40 percent of the economic advantage of that fuel-cycle option derived from savings in the costs of waste storage and disposal.[34] Moreover, arguments were made within NRC to continue to push recycle aggressively in terms of the waste management implications of failing to do so.[35])

The shifting definition of commercial high-level waste had some pragmatic consequences. When, in 1970, AEC tied the definition to a particular fuel cycle, they set off a critical sequence of events. For once the presumption is made that spent fuel contained valuable components, there are strong economic incentives to extract those components as rapidly as possible. At the same time, safety considerations dictate that large volumes of the residual material should not accumulate. The combination of those two factors led AEC, at the same time it released its definition, to promulgate a regulation requiring that high-level commercial waste be transferred to the Government within 10 years from the time irradiated fuel rods were removed from the reactor.[36] When AEC acted, this requirement did not appear to pose difficulties as a repository at Lyons, Kans., was being developed. When that effort was terminated, however, the strong need arose to have an alternative available to receive the waste from reprocessing plants. In particular, the decision to construct a retrievable surface storage facility (RSSF) can be directly traced to the need to satisfy that regulatory exigency.[37]

As spent fuel emerged more clearly as a possible category of high-level waste, policymakers had to reorient some of their programs. NRC, for instance, was in the midst of the "S-3" hearings on the environmental effects of reprocessing and waste management. The definitional changes forced new analyses to be performed and added to the regulators' uncertainty about whether their actions would be sustained in court. In addition, deferral of reprocessing increased pressure on utilities to find space to store spent fuel assemblies. Over three times as much room would be required.[38] The Carter administration's decision to request authority to construct an away-from-reactor facility was a response to that perceived problem.

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[29] "Plutonium Recycle Program at Hanford," AEC-960, Mar. 14, 1957, p. 1.

[30] App. F, 10 *Code of Federal Regulations*, pt. 50.

[31] See, for example, *Final Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors* (GESMO), NUREG-0002, U.S. Nuclear Regulatory Commission, 1976, pp. xi-19—xi-23.

[32] Memorandum to the President from Robert Fri, Sept. 7, 1976, p. 19.

[33] *GESMO*, op. cit., p. ES-16. See also Spurgeon Keeny, Jr., et al., *Nuclear Power Issues and Choices* (Cambridge, Mass.: Ballinger, 1977), p. 323.

[34] *GESMO*, op. cit., p. 11-78.

[35] "Pu Recycle Issue," SECY-75-37, Feb. 19, 1975, p. 8.

[36] See app. F, 10 CFR 50.

[37] "Management of Commercial High Level Radioactive Wastes," SECY-2371, Mar. 17, 1972, p. 13.

But the major significant consequence of the shift was the injection of a novel issue into the waste management debate: could spent fuel be disposed of as safely and efficiently as waste from a reprocessing plant? The GESMO analysis answered that question affirmatively and concluded that there is "no clear preference for any specific fuel-cycle option based on radioactive waste management considerations."[39] But others, particularly advocates from the nuclear industry and some geologists, were not as persuaded. They argued that differences in volume, heat generation, amount of long-lived toxic radionuclides, and homogeneity of chemical composition all worked to increase the ease and lower the risk of disposing reprocessed waste. This controversy raged intensely for a time. There appears to be an emerging, although not complete, technical consensus within this country that "considerations of the management of [high-level waste] do not put significant constraints upon choices among various fuel cycles."[40] That view has recently been supported in the report of the International Nuclear Fuel Cycle Evaluation study group.[41]

Storing Radioactive Waste

Early records of waste management policymaking blur the conceptual difference between storing and disposing of radioactive waste. Over the years seemingly more precise conceptual distinctions emerged even though semantic confusion persists. Nevertheless, some definitional ambiguity still remains. The purpose of this section is to clarify the meaning of the two terms, to show how thinking about storage has evolved, and to specify some remaining policy dilemmas dealing with waste storage. We shall then consider the issues surrounding radioactive waste disposal in the next three sections.

The connotations associated with the terms storage and disposal can be misleading. Storage is usually linked to temporariness, disposal with permanence. Phrases such as "interim" are connected to the former term while "ultimate" and "final" are associated with the latter. It is quite possible for the same technological system to be viewed by some individuals as an interim measure while others see it as providing a final resting spot for waste. Thus, the designation of a system depends mainly on what can be done with it sometime in the future, a fate that cannot be forecast at the start with complete certainty. A more conceptually clear way to distinguish storage from disposal is based on the degree of effort that must be exerted to gain access to and active control over the waste material. At the extremes, spent fuel management at the reactor would be an example of storage while extraterrestrial shipment or transmutation would be instances of disposal. In between, all other technical approaches must be viewed as possessing some mixture of storage and disposal characteristics. For instance, NRC's draft requirement that a geologic repository be designed to facilitate the retrieval of the waste for 50 years after emplacement operations cease transforms geologic "disposal" into an elaborate method of storage.[42] For simplicity sake, we shall call those approaches which require at least as much effort to gain access to and control over the waste as burial in geologic formations without provisions for retrievability "disposal options." Those approaches requiring less exertion will be termed "storage options." This shorthand should not encourage the reader to forget that a continuous range exists between the endpoints of "storage" and "disposal."

This country's first large-scale excursion into waste management centered on developing storage systems. The vast tank farms at the Hanford Reservation, as we noted above, were established to hold the liquid waste produced in conjunction with the nuclear weapons program. The functions of the system were ambiguous at the time they were created and, to some extent, remain so today. There is some evidence to suggest that those involved at Hanford, particularly during the pre-1970 period, viewed the tanks, or some relatively minor modification of them, as a perfectly viable **final approach** to managing the wastes.[43] Indeed, the view is advanced in some early documents that the tanks would maintain their integrity for hundreds of years, just the length of time needed for the two biggest "problem isotopes," strontium and cesium, to decay.[44] Certainly, this view of perpetual tank storage was the one which prevailed in the design of the commercial waste management system used at the Nuclear Fuel Service's (NFS) reprocessing plant.[45]

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[38] *GESMO,* op. cit., p. xi-17.

[39] Ibid., p. iv-H6.

[40] L. Charles Hebel, et al., *Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management* (APS Report), *Report of Modern Physics* 50, January 1978, p. 5107.

[41] See, *International Nuclear Fuel Cycle Evaluation,* IAEA, Vienna, Austria, 1980.

[42] *Federal Register,* Mar. 5, 1981.

[43] For examples of the ambiguity, compare Atomic Energy Commission 180/5, "Disposal of Radioactive Wastes," Mar. 30, 1956 with Atomic Energy Commission 180/6.

[44] See, "Hanford's Highly Radioactive Waste Management Program," AEC 180/30, Apr. 5, 1968, pp. 6-7.

[45] See U.S. Congress, Joint Committee on Atomic Energy, hearings, *Chemical Reprocessing Plant,* 88th Cong., 1st sess. (Washington, D.C.: U.S. Government Printing Office, 1963).

By 1956, however, another position began to gain currency within AEC. Those who took that new tack argued that tank storage was not the "ultimate solution" to the waste management problem . . . if only because it was too expensive over the long run.[46] Instead, they advocated a robust research program to find a technical option that could be employed to manage newly created waste material. Thus, rather than being a final measure, tank storage would simply serve as an **interim approach** pending the discovery of something better.

There were a number of AEC staff and policymakers who saw the storage system serving a third function: a reservoir containing materials of economic importance. Efforts were initiated to extract from the waste soup radionuclides that were commercially valuable. Strontium and cesium would be employed as heat sources; cesium would be used in a project to irradiate foods; the heavy metals would be destined for industrial applications.[47] In this way, some of the costs of the waste management program might be offset. There was sufficient enthusiasm for this approach in the late 1960's that one firm reached an agreement with AEC to build a fission product extraction plant at Hanford. But before construction began the economics of the endeavor turned sour and the company canceled its plans. Nevertheless, the idea of fission product recovery of commercially valuable material would not die easily. As late as 1975, JCAE was pushing the concept.[48] Even today, some people still hope to see some commercial venture to utilize fission products.

The next major initiative in the waste management program was the effort to develop a disposal facility at Lyons, Kans. A combination of technical weaknesses and a lack of attention to the institutional aspects of the project contributed to its early and painful demise. AEC, thus, found itself in early 1972 without a repository and without a fallback plan to find another site for one in the near term.

AEC's response was to propose constructing a series of aboveground engineered structures—mausolea—which would be used to store solidified, reprocessed waste from the commercial sector.[49] The explicit rationale for this undertaking presented to AEC was:[50]

> If the problems of gaining public acceptance of the concepts of storage [sic] in geological formations cannot be overcome in the near future, an available option is retrievable storage in carefully engineered man-made structures and acceptance of the idea that man must maintain close control over the waste so stored at least until geologic storage [sic] becomes acceptable or until development of new technology opens up new approaches not now practical.

Storage in RSSF would be used as an **interim approach** pending a more hospitable political environment.

Unfortunately, AEC took other actions over the next 2 years which, at the very least, sent a set of mixed signals to those interested in waste management policy. Perhaps because fiscal year 1975 was a tight budget year, AEC had to severely cut back its expenditures devoted to advancing its capabilities for geological disposal or for discovering new alternative technologies. That circumstance left the impression in the minds of some concerned individuals that the RSSF's function could very well evolve into one of **final disposition** rather than the interim one which AEC asserted. That was precisely the critique of the RSSF leveled by the Environmental Protection Agency (EPA):

> A major concern in employing the RSSF concept is the possibility that economic factors could later dictate utilization of the facility as a permanent repository, contrary to the stated intent to make the RSSF interim in nature . . . [I]t is important that [environmental factors] never be allowed to become secondary to economic factors in the decision making process. Vigorous and timely pursuit of ultimate disposal techniques would assist in negating such a possibility . . . However, the draft statement does not contain an adequate description of a program to develop such a disposal system nor does it reflect either the priority given to programs by the AEC nor an indication of the resources required.[51]

More than any other single criticism, the one advanced by EPA and supported by other commentators provide the coup de grace for the RSSF concept. In this instance, it was clear that it was unacceptable to proceed with a storage system unless there were unambiguous assurances that the system would not degenerate into a final disposing spot for the waste.

Since the cancellation of the RSSF, Federal activity has concentrated on the development of disposal technologies, particularly mined geologic repositories. A number of generic studies have been undertaken and exploration of specific sites commenced. But because of the program's relatively late start and its slow progress and because of possible lengthy delays in the start of commercial reprocessing, concerns arose as early as 1975 that a number of operating reactors would run out of room to store their discharged spent fuel onsite.[52] Should that occur and if there were no alternative locations to place the material, then the reactor would be forced to shut down. Between 1975 and 1977, the private sector floated proposals to construct large-scale facilities to hold excess spent fuel from utilities. Yet, for a variety of reasons, many unclear to this day, those proposals never reached fruition.

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[46] Atomic Energy Commission 180/5, op, cit., p. 5.

[47] Memorandum, Frank Pittman to James Ramey, Feb. 25, 1965, pp. 7-8.

[48] This matter arose during hearings on the Atomic Energy Commission's fiscal year 1976 budget.

[49] See WASH-1539.

[50] "High Level Waste Management," SECY-2271, Jan. 25, 1972, p. 3.

[51] EPA response to WASH-1539, Nov. 15, 1974, p. 2.

[52] *LWR Spent Fuel Disposition Capabilities, 1975-1984*, ERDA-25, Energy Research and Development Administration, 1975.

It was in this context that the newly elected Carter administration announced its spent fuel policy in October 1977.[53] Under it, title to the spent fuel would be transferred to the U.S. Government. The fuel would be transported to a Government-approved away-from-reactor site at the utility's expense. A one-time fee would be paid by the utility that would cover the Government's costs of storage and disposal. In addition, the administration expressed a willingness to accept limited amounts of foreign spent fuel for storage and disposal if such an action contributed to the achievement of the country's nonproliferation goals. At the time this policy was first articulated, many of its modalities and logistics were unsettled. The administration, for instance, did not necessarily propose to construct a new storage facility on its own. It was prepared to contract with the private sector for storage services.

Thus, the away-from-reactor storage proposal was initially designed to serve four different functions. It prevented the shutdown of reactors pending repository development; it would provide time for the geologic disposal program to mature; it would provide some foreign countries at least a limited incentive to forego fuel reprocessing thereby reducing the spread of nuclear arms; it would provide a means of conserving potentially valuable material since the plutonium and uranium in the spent fuel would be accessible should reprocessing ever be permitted and become economically viable. Later on, the away-from-reactor program was also advocated by those who saw a fifth function: the away-from-reactor, by relieving some of the pressures on the nuclear industry, would reduce the likelihood that the industry might use its large political clout to force a premature decision on a geologic disposal plan. Finally, the administration carefully distinguished its policy from the RSSF project. Not only did it announce that disposal remained a high priority, but it committed substantial resources toward that end. It should be noted, however, that those actions did not deter critics who maintained that an away-from-reactor would also end up as the final resting place for the stored waste either because of the short-term economics or because DOE would lose its incentive to develop repositories.

The administration's initiative to involve the public sector in the provisions of storage facilities placed the issue of waste management on Congress' legislative agenda after a hiatus of nearly 5 years. A plethora of bills were introduced dealing with a wide range of waste management issues. In July 1980, the Senate passed S. 2189, which, in many respects, marked an abrupt change from the policies that had evolved over the last decade.

In particular, the bill blurred the conceptual distinction between storage and disposal. The bill defined "disposal" to include the:

> . . . long-term isolation of material, including long-term monitored storage which permits retrieval of the material stored.[54]

Moreover, it provided for the construction of a "disposal" facility that would:

> . . . permit continuous monitoring, management, and maintenance of the spent fuel and high level radioactive waste for the foreseeable future, allow for the ready retrieval of any spent fuel and high level radioactive waste for further processing or disposal by an alternative method, and safely contain such high level radioactive waste and spent fuel so long as may be necessary, by means of maintenance, including, but not limited to, replacement of such a facility.[55]

That section had the effect of radically redefining the idea of disposal. Although geologic means could still be pursued, indeed the bill called for that program's acceleration and a demonstration repository, mined facilities were no longer to be seen as the dominant technique of disposal. The Federal Government's obligations in that regard could be met by the construction, monitoring, and continuous replacement of a set of mausolea. In fact, the bill sanctioned a return to an RSSF-like approach.

Senate bill S. 2189 viewed the function of storage as essentially twofold: a means of preserving options to protect the resource value of the spent fuel and a method of postponing, perhaps forever, commitment to a technique of more secure disposal. It was that last vision that elicited the most hostile response. Critics maintained that the bill, by diluting the commitment to disposal, would permit an inequitable transfer of risk from this generation to generations in the future. The House of Representatives passed a bill more responsive to those concerns. And despite last-minute, strenuous efforts to compromise the two versions, no mutually acceptable legislation could be hammered out. The 96th Congress adjourned with the issue of storage still unresolved. The new Reagan administration abandoned the away-from-reactor storage proposal, believing that the private sector ought to tend to the storage of spent reactor fuel.

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[53] *DOE Information Bulletin*, R-77-017, Oct. 18, 1977.

[54] Senate Bill 2189, sec. 201 (3).

[55] Ibid., sec. 402 (b).

Utilizing Knowledge of the Earth Sciences in Developing a Waste Management Program

Since the late 1950's, when the policy was informally adopted of disposing of at least the high-level waste from the commercial sector, the front running technical strategy has been emplacement in repositories mined by conventional methods. At a very early stage, earth scientists and mining engineers were involved in conceptually crafting the AEC waste management program. Those same professionals have intermittantly provided guidance to AEC and its successor agencies over the last quarter century. In this section, we shall explore how the basic scientific and technological knowledge influenced the design of the waste management program. We shall in particular note how, as the program evolved, earth science became a more central element of the effort and how relatively simple—but elegant—earth science conceptions were displaced by more complex ones.

The first major involvement of earth scientists to consider the issue of waste disposal began in February 1955. Then AEC contracted with NAS to provide advice on how to structure the research that could establish the scientific basis of a waste management program. NAS appointed an eight-man committee of prominent geologists, hydrologists, and geophysicists. The group met several times and convened a major conference on the question at Princeton University during September 1955. Two years later, the committee issued its first report, one which we noted above was extremely influential in orienting waste management policy for two decades.[56]

The problem the committee addressed was, in many repects, unprecedented: how to design a mechanism for isolating highly toxic radionuclides from the biosphere for long, possibly geologic, periods of time. At the time its deliberations began, the group took as a given the fact that the waste materials would be dissolved, at relatively low concentrations, in some liquid. This constraint strongly affected the way the committee proceeded to puzzle through the problem. In particular, several alternatives were quickly discarded. The use of granite and other crystalline rock quarries was discounted because of the near impossibility of sealing the facility against leaks. The use of permeable noncrystalline rocks such as sandstone and limestone by themselves was precluded for similar reasons. The uncertainties of sealing nonpermeable materials such as clay and shales seemed too formidable. Other options, such as injection of the waste into deeply lying porous media interstratified with impermeable beds, were deemed to be feasible in principle but so plagued with significant problems that they were impractical in the short run.[57]

One technique did, however, strike the committee as rather promising. It involved the use of salt, either bedded or domed, cavities: "Abandoned salt mines or cavities especially mined to hold waste are, in essence, long-enduring tanks."[58] What made salt the appropriate and in some sense the elegant solution were two factors. First, water will not pass through a relatively stable salt formation to carry away the waste. Second, should any fractures arise in the salt, they would soon be self-sealing because of the plastic flow properties of the material at typical repository depths. The NAS committee believed it had found an autonomous mechanism, based on immutable physical principles, for ensuring that the toxic waste would be reliably isolated for thousands of years.

It is essential to understand the premises behind the committee's espousal of salt. The committee's position was founded on the assumption which the group explicitly recognized required substantiation, that the material's chemical and physical properties would not be radically altered when the salt was exposed to the heat and radiation generated by the waste. If that assumption held, then all that was necessary was to find a suitable salt formation, dig a hole, backfill it with salt, and walk away.

During the next 4 years, small-scale research projects were initiated to test the validity of the committee's assumption. Those investigations were "encouraging," but there remained a variety of difficulties which, in the words of one report, were "unique to liquid waste disposal."[59] Cavity alterations and radiolytic reactions were observed. And while the technical operatives expressed optimism that those obstacles would be overcome, it became evident that the salt concept had not been validated.

As the 1960's began, substantial alterations in fuel reprocessing technology were being made, the most important of which involved a twentyfold reduction in the volume of liquid waste. That breakthrough, while substantially increasing the waste's heat and radiation density, facilitated transforming the material into a solid form. That prospect, in turn, redirected AEC's fledging research program. AEC contractors, urged on by the NAS committee, set out to examine the effect of dry packaged radioactive wastes on salt. Therein lie the origins of the first major in situ experiments—called

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[56] NAS/NRC, 1957, op. cit.

[57] Ibid., pp. 81-103.

[58] Ibid., p. 5.

[59] R. L. Bradshaw and W. C. McClain (eds.), *Project Salt Vault: A Demonstration of the Disposal of High-Activity Solidified Wastes in Underground Salt Mines*, ORNL-4555, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1971, p. 1.

Project Salt Vault—undertaken to obtain the data needed to design a waste repository.

To say that AEC vigorously pursued these efforts to validate the salt assumptions would vastly overstate the case. Funds to support Project Salt Vault had to be "bootlegged" from other efforts by researchers at the Oak Ridge National Laboratory. With some difficulty they put together enough resources to carry out studies in the Carey Salt Mine at Lyons, Kans., between 1965 and 1967. Fourteen irradiated fuel assemblies taken from AEC's Experimental Test Reactor were used to simulate solidified waste. The assemblies were placed in a ring-like arrangement in the floor of the mine. Furthermore, electrical heaters were installed to raise the temperature of a large quantity of salt in the central pillar in order to obtain information on its in situ structural response to heat. In spite of the rather high radiation doses to the salt and in spite of the high thermal loading, no measurable radiolytic or excessive structural effects in the salt were observed. While hardly a definitive or exhaustive test, the results of Project Salt Vault at the time did lead many in AEC to believe that the salt assumptions were largely valid.[60]

Although the AEC leadership had little enthusiasm for this experimental effort when it was first proposed or even as it was being conducted, nearly 3 years after it was concluded the undertaking took on special significance. For in 1970, AEC decided to move ahead and develop a full-scale facility at the Carey Salt Mine.[61] AEC's managers relied heavily on the Salt Vault data to support their new initiative. Indeed, the environmental impact statement assessing the proposed Lyons repository contains no geophysical information gathered at the site after the conclusion of Salt Vault.[62]

The Kansas project was ultimately canceled because water from a nearby solution mining operation could not be easily accounted for and because it was hard to persuade critics that the roughly 20 oil and gas boreholes could be reliably plugged. The abandonment of the Carey Mine site, however, did not undermine AEC's faith in the salt assumptions. In fact, as we detail later on in this essay, the Commission quickly moved to identify other sites that might be suitable for a repository.[63] Nevertheless, it committed the preponderance of resources to searching for locations where the emplacement media would be salt. This almost single-minded preoccupation with a single geologic formation is well reflected in the comprehensive "Technical Alternatives Document" which contains essentially no information on "nonsalt" repository options.[64]

Up until this time those earth science specialists working in and for AEC, as well as those associated with the NAS's advisory committee, were a relatively closed group. They all accepted the salt assumptions and felt comfortable with a waste management policy that was predicated on them. Over a period of nearly 20 years, that perspective has two important consequences for the orientation of AEC's research program. First, comparatively little effort was devoted to considering how the geologic environment outside of the salt formation might contribute to isolating the waste. Second, there was considerable reluctance to investigate other emplacement media as a possible alternative to salt.[65]

By the mid-1970's, because of the abandonment of the Lyons site and because of the growing controversy over nuclear power, waste management policy became salient to a wider range of individuals, members of the general public and technical specialists alike. Many of the new participants were unable to accept the prevailing salt assumptions. At first, the criticism of the Government's waste policies came from citizen groups generally opposed to nuclear power. The salt assumptions were rejected in those criticisms as concerns were raised about brine migration, decrepitation, the problem of breccia pipes, and the corrosiveness of salt solutions, concerns which had all been considered and largely discounted by the Commission. Later on, however, more subtle challenges were advanced. These did not reject the salt assumptions but held them to be problematic and therefore urged that different technological strategies be explored.

Perhaps the earliest influential instance of the latter brand of skepticism was the report of the American Physical Society (APS) study group on nuclear fuel cycles and waste management.[66] The APS study group did not explicitly reject the salt assumptions. On several occasions the report's authors stated that there was no basis for believing that a salt repository could not be developed.[67] Yet, the conceptual thrust of the APS study was strikingly different from that which had dominated since the mid-1950's. Instead of accepting the elegant solution of a relatively isolated, autonomously self-correcting salt formation, the group stood back and focused on the larger hydrogeologic environment.

That environment was, in their view, the critical element in designing a waste disposal facility. While the behavior of the emplacement media per se was important, it need not be determinative. For if sufficiently long hydrological flow paths were available and if sorptive material were present along those paths, then the requirements that the emplacement media be self-sealing and impermeable might well be superfluous.

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[60] See, for instance, memorandum, George Kavanagh to Commissioners, "Background Information on Long Term High-Activity Waste Management," Sept. 8, 1967, p. 2.

[61] "Solid Radioactive Wastes: Salt Mine Storage," AEC 180/81, Apr. 23, 1970.

[62] *Radioactive Waste Repository, Lyons, Kansas*, U.S. Atomic Energy Commission, Washington, D.C., 1971.

[63] "High-Level Waste Management," SECY-2333, Feb. 24, 1972, p. 4.

[64] *Alternatives for Managing Wastes From Reactor and Post-Fission Operations in the LWR Fuel Cycle*, ERDA-76-43, Energy Research and Development Administration, Washington, D.C., 1976, pp. 24.49-24.80.

[65] "Solid Radioactive Wastes: Long-Term Storage in Central Kansas Salt Mine," AEC 180/87, June 12, 1970, p. 5.

[66] *American Physical Society*, 1976.

[67] See *American Physical Society*, p. S139, for example.

> Based on our analysis of hydrogeologic transport we expect that the conditions that would provide for satisfactory geologic isolation of radioactive waste—i.e., a suitable groundwater environment—are present in a sufficient number of places that several acceptable sites in *different geologic media* can be located without difficulty in the immediate future.[68] [Emphasis in original.]

Thus, the APS report recommended that a broader program of geologic research and development be instituted.[69]

That position, on the surface, appears inconsistent with the group's unwillingness to reject the salt assumptions. After all, if those assumptions held, then substantially greater attention to geohydrology and ground water modeling would itself be superfluous. The elegant solution had not been overthrown.

What made the APS report internally consistent was the introduction of "anthropogenic concerns."[70] Even if the formation compensated for natural disruptions, salt, particularly domes, by its very nature was attractive to those looking for oil, gas, potash, or even a storage site. Future generations searching out those resources might inadvertently disrupt the repository and bring on "possibly serious consequences" unless the environment outside the emplacement media also contributed to the isolation of the waste. But if one considers the environment of the salt, there is no reason why the environment should not be considered for other media. In the group's view such a course would only be "prudent"—hence their conclusions and recommendations.

While the APS study did not explicitly reject the salt assumptions, another report published shortly thereafter came quite close to doing so—at least in the context of prevailing premises about repository operation. Since the early 1950's, the U.S. Geological Survey (USGS) had been supporting AEC and its successor agencies in their waste management research. In the mid-1970's the USGS involvement had begun to intensify. The two agencies' interaction was not entirely without conflict, which centered on the nuclear organization's commitment to salt. For a period of time, USGS personnel tried to reach an accommodation on that issue with those managing the waste program. Those USGS scientists, however, eventually came to believe that their concerns about salt—some of which reflected the views of nuclear opponents—were not being given proper consideration.[71]

In a rare action by traditionally cautious bureaucrats, the USGS scientists publicly expressed their concerns in Circular 779: "Geologic Disposal of High-Level Radioactive Wastes—Earth Science Perspectives."[72] The bulk of the work engendered little controversy; the middle section, however, raised some disturbing—although not entirely novel—questions and in doing so conferred a legitimacy to those technical concerns about disposing of waste in salt which heretofore had been lacking. The USGS argument asserted that if relatively hot waste—say 5 to 10 years old—is introduced into a salt repository the potential exists for the repository to lose its integrity. That circumstance would arise because the thermal pulse would aggravate "the mechanical disturbances initiated by mining the repository and the chemical disturbances caused by the introduction of material—not in chemical equilibrium with the rock mass."[73] Should the repository fail, the salt would not itself retard the migration of the nuclides. Thus, USGS arrived at precisely the same conclusion, although by a different and—from a policy perspective—substantively significant route, as did the APS study group.

It would be misleading to infer from this discussion that AEC and its successors were unbending in their commitment to salt. Beginning in 1973 and accelerating in the next few years, AEC and its successor agencies sponsored research in other media.[74] In 1976, ERDA announced a program to examine a variety of emplacement media to find acceptable repository sites and that the third facility might be constructed in some media other than salt.[75] Yet, if policymakers at AEC and ERDA were prepared to open the door for geologic diversity, they saw little reason to abandon the salt assumptions. However, as more and more technically competent groups and individuals inside and outside the Government questioned the salt orthodoxy, it became clear that this fundamental earth science controversy had to be resolved. The forum for that resolution came to be the Interagency Review Group on Nuclear Waste Management (IRG) established by President Carter in April 1978.

A working subcommittee of IRG, chaired by the Office of Science and Technology Policy (OSTP), was assigned the task of crafting a paper synthesizing the status of knowledge about waste isolation using geologic repositories.[76] Representatives from DOE and USGS took an active role in the preparation of the report. The study underwent four major revisions over the course of slightly over 6 months. It was reviewed both by a specially appointed advisory committee and by hundreds of individuals from the earth science community.[77]

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[68] Ibid., p. S138.

[69] Ibid., p. S7.

[70] Ibid., p. S139.

[71] Confidential interviews with author, 1980.

[72] The circular was written by J. D. Bredehoeft, A. W. England, D. B. Stewart, N. J. Trask, and I. J. Winograd.

[73] Circular 779, pp. 4-5.

[74] SECY-2271, p. 3.

[75] *Information From ERDA*, "ERDA Studies Geologic Formation Throughout Nation for Data on Potential Sites for Commercial Nuclear Waste Disposal," No. 76-355, Dec. 2, 1976.

[76] *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste*, app. A, TID-28818 (draft), Interagency Review Group on Nuclear Waste Management, Washington, D.C., October 1978.

The section dealing with salt repositories in the OSTP paper represented something of a compromise between the views of DOE and USGS; in tone and thrust it was quite akin to the APS study. In essence, the OSTP document questioned, but did not overturn, the salt assumptions. At the same time, it reiterated the concerns of APS and USGS about the importance of viewing the waste isolation mechanism as an entire system of waste form, package, repository structure, and hydrogeologic environment.

The evolution of earth science perspectives from the early 1950's to the late 1970's was striking and profound. While no one dismissed out of hand the concept of a mined repository, the elegant solution of salt came to be questioned—and for some—rejected. In its place has come a more complex view of what needs to be done to ensure that waste will be reliably isolated for geologic periods of time. In the three sections that follow—site selection strategy, waste packages, and regulatory philosophy—we shall be recapitulating some of the themes raised here. For those aspects of the waste management problem came critically to depend on the status of geologic science and technology.

Developing a Search Strategy For Sites

Siting strategies fall along a conceptual continuum. A process by which sites are randomly examined until an acceptable one is found demarcates one extreme. The other end point corresponds to a strategy in which all possible sites are comprehensively compared along a variety of dimensions prior to selecting one. In the pragmatic world of seeking a location for a repository, neither extreme is appropriate. The former approach fails to take advantage of existing knowledge to eliminate a priori sites that are unsatisfactory. The latter approach is too demanding of knowledge, time, and resources. In between the two extremes, a range of "mixed" strategies do exist, and they can be distinguished in terms of how proximate they are to either end point of the continuum. Indeed, the history of site selection strategies is a chronicle of movement away from the more random end toward the more comprehensive one.

AEC's initial site selection strategy can be inferred from the process which at least tentatively selected the Carey Mine in Lyons, Kans., as the location of the country's first repository. As the reader will recall, personnel from Oak Ridge National Laboratory used that abandoned mine for experiments designed to determine the thermal and radiation effects of high-level waste on salt. They were led to that particular type of geologic formation by the strong endorsement given salt 6 years earlier by NAS.

Those involved in this Project Salt Vault recall that their efforts enjoyed the support of the local citizenry.[78] Four factors contributed to this climate of acceptance: 1) the experiment was designed from the beginning to be reversible—once it was over all the waste was completely removed; 2) consultations were held with local groups before the project began; 3) efforts were made by Oak Ridge staff personnel to conduct the studies in full view of the Kansas population; and 4) once the research started, regular tours were conducted in which the general public could visit the mine.

Project Salt Vault might have become an isolated footnote in the saga of nuclear policymaking had not two circumstances intervened. The first was a fire which occurred in 1969 at an AEC weapon's components facility in Rocky Flats, Colo. The accident gave rise to a large volume of low-level, plutonium contaminated debris. Following its standard operating procedures, the managers of Rocky Flats forwarded the waste to the National Reactor Test Station in Idaho for storage. That action outraged Idaho's political leadership who saw no reason why their State should become the dumping ground for waste created in Colorado. They acted and ultimately extracted a commitment from Chairman Seaborg that all of the waste would be removed by the end of the 1970's.[79] That pledge necessitated the construction of a disposal facility. The second circumstance, which will be discussed below, was the emerging regulatory policy on commercial waste management. That evolving policy also provided a basis for AEC to go beyond the early experimental efforts at the Kansas salt mine and to develop a repository.

Thus, confronted with the need for a repository, AEC's siting strategy was relatively straightforward. Because of the prevailing geologic assumptions held within AEC and among its contractors, host formations other than bedded salt were not even considered. This left about 500,000 mi^2 of land overlying bedded salt within the continental United States. That area was further reduced because only salt deposits 200 ft thick and lying within 2,000 ft of the surface were deemed "to be the most desirable for the first waste repository."[80] The largest area meeting these criteria lay in central Kansas; there were two smaller areas in Michigan and one in west central New York.

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[77] Ibid., Preface.

[78] Confidential interviews with author, 1975.

[79] Letter from Seaborg to Senators Church and Jordan, June 9, 1970.

[80] Atomic Energy Commission 190/81, op. cit., p. 10.

In the technical analysis provided AEC, none of the alternative sites had a clear-cut advantage in terms of their geologic characteristics although the New York location was in an area of lower tectonic stability. The Michigan site was burdened by the fact that part of it underlay metropolitan Detroit. But finally, AEC decided on the Kansas site and in particular the experimental mine in Lyons because:

1. There had been detailed information gathered on the area as part of Project Salt Vault.
2. There was a sense of confidence in receiving a "favorable reception on the part of local and state officials and private citizens."
3. There was a recognition that necessary investigations to prove out the acceptability of the other sites would result in considerable delay "estimated on the order of two years."[81]

The choice of the Lyons location turned out to be unfortunate. The site developers encountered several major technical problems and, as we shall point out below, substantial political controversy as well. Less than 2 years after its selection, the location was abandoned by AEC.[82]

How AEC's successors crafted a strategy for site selection in the next iteration of activity is not nearly as straightforward. What is undisputed is this chain of events. The aftermath of the Lyons endeavor had created an environment that was not conducive to further site exploration. As a result, early in 1972, USGS was asked by the AEC headquarters staff and personnel from Oak Ridge to summarize the available geologic and hydrologic knowledge of selected rock types, particularly salt, in other parts of the country and to assess their suitability for a waste repository. The USGS study identified approximately a dozen regions where candidate sites might be found. That fall, the choice was made to concentrate further exploration in the Permian basin in eastern New Mexico. The choice seems to have been made because the other regions featured salt domes and anticlines (Guld and Paradox basin) rather than bedded salt, because they were in areas of heavy population (Salina basin), or because the salt was too far underground (Williston basin).[83]

Four candidate sites were examined in more detail and out of that investigation came the decision in favor of a site located 30 miles east of Carlsbad. Additional drilling and geophysical exploration, however, indicated that that location was unsatisfactory. Eight additional areas were studied and their consistency with eight criteria was measured. From that process emerged the site for what is currently designated the Waste Isolation Pilot Plant (WIPP), a facility now being considered as a repository for waste from the defense program.[84]

The official history of the WIPP site selection strategy leaves the reader with the impression of an entirely scientific and rational process driven simply by the force of disinterested analysis.[85] To a large degree, that is likely the case. However, that history contains at least one minor point of contention and one significant omission. The first has to do with who made the decision to focus on the Permian basin. According to the official version, "USGS and [Oak Ridge] selected Eastern New Mexico as the area in the United States best satisfying their site-selection guidelines."[86] This was presumably at a meeting in Carlsbad in November 1972. USGS personnel who attended that meeting, however, maintain that the decision to select the Carlsbad area for further exploration was made 2 months previously by AEC headquarters staff and Oak Ridge personnel. The November meeting with USGS simply ratified the initial choice.[87]

But the omission could render the point of contention moot. Even before the technical problem which ultimately doomed the Lyons project arose, AEC officials had met with representatives from New Mexico. As a memorandum detailing that contact reports:[88]

> Their interest in obtaining a Federal waste disposal facility came from a worsening of the competitive position of the U.S. potash industry . . . as highly automated Canadian mines in rich potash seams began to come into production. This translated into a loss of jobs and a blow to the Eddy County/Lea County economy. Preliminary discussions with potash interests, the Carlsbad Chamber of Commerce and the State Department of Development indicated that there was a potential for a favorable political atmosphere.[89]

The Interagency Review Group (IRG) went on to say, however, that "there is a risk that as a result of applying nontechnical criteria first, organizational and political commitments might develop to such a degree that insufficient weight might be given to technical data developed later on."[90]

It is fair to say that opponents of the Lyons and WIPP sites—as well as some relatively disinterested observers—believed that technical criteria had been subordinated to political and bureaucratic ones. This impression was fostered, in part, by the fact that AEC and its successor agencies made substantial public commitments to the projects and had no alternative sites available as backups. Under those circumstances it was hard to convince the skeptical that the sites would be evaluated in an objective fashion.

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[81] Atomic Energy Commission 180/87, op. cit., pp. 4, 16.

[82] Briefing Summary, "Program Review—High Level Waste Management," Feb. 2, 1972.

[83] *Waste Isolation Pilot Plant, Draft Environmental Impact Statement (WIPP-DEIS),* DOE/EIS-0026-D, Department of Energy, April 1979, pp. 2-4—2-6.

[84] The announced plans for WIPP have changed repeatedly. While currently being considered for only the disposal of defense transuranic waste, at other times the disposal of defense high level waste and the possible disposal of 1,000 commercial fuel rods have been proposed.

[85] *WIPP EIS,* op. cit., pp. 2-3—2-12.

[86] *WIPP EIS,* op. cit., p. 2-6.

[87] Confidential interview with author, 1980.

[88] Owen Gourmley to Dorner Schueler, "Change in Exploration From Kansas to New Mexico," Feb. 1, 1979.

[89] *Subgroup Report,* op. cit., p. 81.

[90] Ibid.

The siting strategy adopted up to this point, then, was closer to the random ad hoc extreme of the continuum than to the completely comprehensive end. That choice was not entirely voluntary. The preoccupation with salt reflected a limited geophysical perspective and knowledge base. Time constraints, such as those imposed by the Rocky Flats fire, the emerging regulatory changes, and the political need to show some progress in geologic disposal, ruled out a more deliberate strategy. Finally, resources were scarce; this also foreclosed a more elaborate strategy.

In truth, neither AEC policymakers nor relevant outsiders were particularly satisfied with that state of affairs. The Lyons experience had clearly indicated the pitfalls of a narrow approach to finding sites. As a result, by the mid-1970's, AEC and later its successor, had begun to create the conditions that would allow for the adoption of a more comprehensive site selection strategy. Time pressures were dampened, at least temporarily, by the RSSF and the delays encountered with reprocessing. The Ford administration was persuaded that major funding increases in the program were required. The earth sciences knowledge base broadened as new research was undertaken.

This restructuring of circumstances was accompanied by a policy decision to expand considerably the approach to site selection.[91] There was to be a comprehensive review of underground formations throughout the United States. Thirty-six States in all were to be surveyed. Fieldwork, including core drilling, was slated to take place in at least 13 States and perhaps as many as 19. More significantly, the search, for the first time, was not to be confined to bedded salt; instead, other host rocks, such as domed salt, basalt, shale, granite, and other crystalline formations were considered. Lower than requested fundings and political objections from Governors and Senators, however, forced a retrenchment in the initial plans. While the expanded program was termed "too ambitious and not well designed for Federal/State and local government interaction,"[92] nevertheless, as a result of this broadened policy, fieldwork was and is still being undertaken in Texas, Louisiana, Mississippi, Washington, and Nevada in search of a location for the first commercial waste repository.

This expansion of the site selection strategy yielded some important dividends. It introduced some redundancy and backup into a program sorely lacking these characteristics. It increased the public credibility of the program. It deflated concerns that a single locality had been selected as the site for the Nation's nuclear waste.

Yet, those returns should not lead one to overestimate the degree to which the new strategy differed from its predecessor. In particular, salt was still viewed as the leading, and perhaps preferred, candidate for host rock. This predisposition, based partly on the greater depth of engineering information and partly on organizational tradition, was reflected in the new program's assertion that the first two repositories would likely be carved in salt. In a more fundamental sense the new strategy was akin to the old in that both mandated a choice and commitment to build a repository once a satisfactory site was found and qualified. To use an analogy, both strategies adopted a decisionmaking principle similar to that used by most house sellers: as soon as an offer exceeds the threshold of "acceptability," it is taken.

Like the order in which technical and nontechnical criteria are applied to screen sites, this decisionmaking rule need not be unsound. But if, as we shall see, there is great uncertainty and strong disagreement about what constitutes the threshold of acceptability, such a decisionmaking principle can be quite risky both scientifically and politically.

There was, in fact, increasing awareness within DOE—as well as among outsiders—of the riskiness inherent in this principle of choice. By the time the Carter administration had taken office and had completed its first assessment of the waste management program, the awareness had grown to the point where alternative selection rules were being publicly discussed. The report of the Deutch Task Force observed that "two basically different philosophical approaches were possible."[93] The first involved comparing the best salt design with the best design in another media. On that basis, the preferred media would be chosen; then several sites in that media would be considered and, presumably, the best one selected for the repository. The second approach, in essence, was the continuation of the status quo. The first satisfactory salt site would be selected and developed in a technically cautious fashion. The Deutch Task Force concluded that "the first approach [is] unnecessarily conservative" and it favored the second.[94]

Although DOE did reconfirm its decision principle, the Deutch Report initiated a process whereby the sensibility of the philosophy was assessed. The forum for this further review was IRG. IRG assigned OSTP the responsibility of analyzing alternative technological strategies for the isolation of nuclear waste in addition to the technical report on the status of geologic knowledge. OSTP began by conceptualizing six strategies in which the first disposal mechanism was a geologic repository. (A seventh postponed the choice of option.) The six alternatives differed in the degree to which there would be intercomparisons prior to site selection. The most restrictive alternative was that of evaluating the suitability of sites on a case-by-case basis—e.g., the status quo. The broadest alternative called for comparison of several sites in several different geological environments. This broad range, it should be noted, was dictated by the technical finding, discussed above, that no particular geologic emplacement medium enjoyed a preferred position.

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[91] *Information From ERDA*, op. cit., Dec. 2, 1976.

[92] *Report on Task Force for Review of Nuclear Waste Management*, DOE/ER-0004 (draft), Department of Energy, Washington, D.C., February 1978, p. 12.

[93] Ibid.

[94] Ibid., p. 13.

As the analysis got under way, the OSTP group soon concluded that the strategies which required intercomparisons possessed certain advantages over the case-by-case approach.[95] Intercomparison of sites would likely increase public confidence, would stand a better chance of satisfying the National Environmental Policy Act and meeting regulatory requirements, and, all things being equal, would improve odds of obtaining a technical success. The case-by-case approach, in contrast, held the advantage of reducing the time it might take to develop an operating facility. That approach would also lessen logistical difficulties that might arise in transporting waste from storage, and entail lower near-term costs.

However, after the first draft of this analysis was circulated within IRG and after informal discussions between staff members of DOE and OSTP, agreement was reached to remove the case-by-case strategy from further consideration. Without any fanfare, then, and for reasons which are still something of a mystery, DOE abandoned its traditional decision principle for repository siting, one which it had reaffirmed only 4 months previously.

The sole remaining issue with respect to siting strategy was how many sites in what geologic environments would be used in the comparison. DOE argued for two or three while most of the rest of the IRG agencies called for four or five. The relatively small difference in number disguised a large difference in substance. For the question was whether the waste management requirements could be satisfied by the existing program or whether an **expanded effort** of geologic investigations would be required prior to the selection of the first repository site. This conflict was ultimately resolved by the President in favor of the more redundant strategy.[96] NRC, in 1981, developed its own procedures that mandated some degree of intercomparison before a site is presented for regulatory review and licensing.[97] In particular, NRC required that three sites in at least two different media be evaluated before a permission will be given to begin repository construction.

Developing a Waste Package

High-level waste streams from a reprocessing plant and, to a lesser extent, spent reactor fuel can be transformed into different waste forms prior to their disposal. The potential variety of form is wide, ranging from essentially untransformed materials to waste forms carefully designed to be compatible, and perhaps in thermoequilibrium, with repository rock. In addition, the waste form itself may be surrounded by other material to protect it further after emplacement in, for example, a geologic repository. The waste form and accompanying material surrounding the waste are termed a waste package.

The state of the art of materials science determines the range of feasible alternatives of waste form and packaging. But there are several issues that must be addressed before the final choice is made. To what degree is there confidence that the geology of a repository will perform its job reliably to reduce demands on the waste form? What economic costs are justified to obtain certain levels of reduction in the long-term risk? What improvements are needed in the waste handling and transportation process itself? How are long-term advantages and disadvantages balanced against short-term ones? In this section, we shall analyze how those issues were addressed, implicitly and explicitly, as the idea of an "acceptable" waste form evolved.

As early as 1957, the AEC staff reported that work was under way to "concentrate and fix the radioactive waste material . . . in a stable, solid medium so that migration of the radioactivity into the environment is eliminated or reduced to safe limits."[98] Among the approaches investigated were conversion to oxide by heating (calcinating), self-sintering with natural earth materials, and fixation of the waste in synthetic feldspars, clays, ceramics, and glasses. Nine years later, research on waste forms had advanced to the point where the NAS Radioactive Waste Committee could observe that it was "favorably impressed with the whole solidification program" and that it was "especially hopeful about glass or ceramic products, because they may be safe from serious leaching and, thus from release of hazardous radionuclides, for periods of centuries."[99]

Despite the promise of waste from research, waste management practices proceeded along a largely independent track throughout this period. An examination of decisionmaking prior to 1970 at the major centers of waste storage/disposal—West Valley, Savannah River, Hanford, and Idaho—illustrates that point.

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[95] Confidential interview with author, 1978.

[96] See announcement of waste management policy by President Carter, Feb. 12, 1980.

[97] *Federal Register* 46, Feb. 25, 1981, p. 13979.

[98] Atomic Energy Commission 180/6, op. cit., p. 28.

[99] National Academy of Sciences/National Research Council, *Report to the Division of Reactor Development and Technology, U.S. Atomic Energy Commission*, 1966, p. 28.

The promise of a waste form that would contribute to safety was ignored most blatantly at the NFS reprocessing plant at West Valley, N.Y. There to the extent that storage of liquid waste in tanks would become the means of disposal—and that appeared to be the most likely outcome at the time—the waste form became the neutralized stream from the extraction process. Implicitly, NFS, AEC, and the State of New York made the judgment that the economic and health costs and the technological uncertainties involved with more sophisticated waste forms overwhelmed any short-term advantages of waste processing. Obviously, such an assessment had as its premise the view that perpetual institutional control of the waste provided as much protection for the public health and safety as other options such as geologic storage.[100] The historical record is unambiguous that NFS, prior to 1970, did not devote any significant effort to designing or developing the alternative waste forms that might be necessary should the strategy of perpetual institutional care be abandoned.

In many respects, the consideration of waste form at Savannah River was also superficial because of the presumed mode of disposal. Beginning in the late 1950's, proposals were advanced to inject the facility's waste into the dense, crystalline bedrock underlying the site. AEC's production division staff believed that three geological barriers would provide independent obstacles to the movement of the mobile waste in slurry form: the crystalline bedrock itself; the saprolite clay overlying the rock; and the aquifer overlying the clay. Alternative waste forms and disposal options were almost totally ignored.[101] This position was taken largely because the production division staff and that of its Savannah River contractor, the Du Pont Corp., believed that:

> Cost estimates indicate the solidification and off-site shipment of the waste . . . would be an order of magnitude greater than placing the waste in bedrock caverns. Furthermore, the hazards involved in processing and shipping this large volume of highly radioactive material might be avoided.[102]

The geology of the Hanford site did not permit a scheme analogous to bedrock disposal. Therefore, other disposal options were considered. This led, in turn, to a somewhat more intensive examination of waste forms. The production division staff and the personnel of Hanford's contractors, Atlantic Richfield Corp., were predisposed to a disposal technique premised on near surface burial of waste in engineered structures. Such an option could easily and inexpensively accommodate the large volumes of waste as well as the fact that a substantial fraction of the liquid waste had been reduced to salt cake to prevent loss of material in case of a leak. Using the near surface burial technique also meant that a waste form only had to be developed for the residual liquor. That could be expediently converted to an aluminosilicate material—a sort of "cement." Those involved in the Hanford operations did recognize, however, that the near-surface disposal option might not provide the long-term safety margins deemed acceptable. Thus, the possibility of solidifying the waste—perhaps using the spray calcinator developed at Richland—prefatory to onsite or offsite geologic disposal was acknowledged.[103] Yet, as in the case of Savannah River, concern was expressed that under such an alternative "costs would be increased."[104]

The only instance where waste management planning and waste form research merged was at the National Reactor Test Station in Idaho. Two factors accounted for this exception. First, geologic and hydrologic conditions militated against final disposal at the site. Second, because only relatively small volumes of waste were involved, it was possible to use stainless steel tanks from the start to store the liquid waste. This, in turn, allowed the operators to avoid neutralizing the waste with large quantities of base. These two differences created at once a need, an incentive, and a favorable technological circumstance for developing a more elaborate waste form. By the end of the 1960's, the Waste Calcining Facility was converting 400,000 gal of waste per year into a granular solid.[105] The solid could be stabilized by heating to 900° C. But even so, it possessed a high leach rate for both strontium and cesium.[106] This waste form, however, would facilitate material handling and transportation at a relatively small economic cost and health hazard. Yet, the form itself, like its more primitive cousins at Savannah River and Hanford, would only contribute marginally to the long-term containment of the waste.

As the 1970's began, then, policymaking on waste form was almost totally subordinated to the more general question of disposal option. Because each of the four waste centers took different stances on the basic issue, it was not surprising that they held divergent views on the secondary one. This pluralism of approach, while perhaps justifiable in a strict technical sense, did lend an ad hoc air to policymaking that made the program susceptible to public criticism. To forestall this and to impose some order on at least a portion of the waste production sites—the new commercial reprocessing plants to be constructed—AEC moved to promulgate appendix F to 10 CFR 50.[107] AEC's resolution of the disposal issue for the private sector led, virtually automatically, to greater closure on the waste form question.[108]

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[100] See the discussion in *Chemical Reprocessing Plants.*

[101] General Accounting Office, *Observations Concerning the Management of High Level Radioactive Waste Material,* Washington, D.C., 1968, p. 27.

[102] "NAS Review of SR Bedrock Caverns Concept," SECY-148, July 28, 1970, p. 2.

[103] *Plan for the Management of AEC Radioactive Waste,* WASH-1202, U.S. Atomic Energy Commission, Washington, D.C., 1972, pp. 13-16.

[104] Atomic Energy Commission 180/30, op. cit., p. 6.

[105] *Plan for the Management,* op. cit., p. 20.

[106] *Alternatives for Managing Wastes,* op. cit., pp. 6.16-6.21.

As noted above, appendix F, the first formal regulatory policy statement for commercial high-level waste disposal, committed the Federal Government to build and operate a geologic repository. Implicit in that commitment was the judgment that such a technical means was the soundest option in terms of the long-range public health and safety. Such a judgment, although not based on any extensive risk analysis, foreclosed the perpetual care alternative used by NFS. It also cast a shadow over the bedrock approach and to a lesser extent Hanford's near surface burial scheme.[109]

Appendix F also resolved, again sometimes implicitly, some corollary issues. There would only be a few repositories built—one would serve the industry's needs up to 2000. Thus, waste would have to be transported to the central repository over long distances from the commercial reprocessing plants which were in various stages of operation and construction. Because transportation of millions of gallons of highly radioactive liquid waste was deemed too hazardous, waste solidification would have to take place at the reprocessing facility.[110]

AEC still had to fill in some critical details: When would conversion to a solid waste form occur? What would be the chemical composition of that solid waste form? Initially, the AEC staff suggested that both those issues be finessed, postponed until some other time. One paper AEC considered called only for conversion prior to the "retirement of the reprocessing facility from operational status," and only for "an AEC-approved solid form."[111] Commissioner Ramey instigated changes which ultimately led to the requirement that the liquid waste be converted within 5 years after their production.[112] Comments from the nuclear industry about the ambiguity surrounding the term "AEC-approved" prompted a clarification which specified that the solid had to be dry as well as chemically, thermally, and radiolytically stable. That clarification hardly defined the solid form unambiguously. Yet, when Chairman Seaborg asked whether more detailed solubility requirements might be included, the Director of Regulation responded:

> A major advantage of the salt disposal concept is that the material has been dry for millions of years, thereby eliminating the importance of solubility considerations. Furthermore, the small but finite solubility of even the most insoluable waste solids developed to date did not provide any additional protection over that provided by the integrity of the salt formation.[113]

Many have applauded the adoption of appendix F as a sound public policy decision. It limited the number of disposal sites and foreclosed the obsolete and hazardous option of disposing liquid waste. But it is critical to recognize the limitations of the appendix's scope. It would never affect the operations at Savannah River or at Hanford, and it did not affect the waste which had heretofore been produced at West Valley. At those sites the same waste management plans, which discounted the potential virtues of waste form, could be implemented. Even for new commercial reprocessing plants, waste form was not viewed as something to pursue for anything other than short-term advantages.

The comments of the Director of Regulation suggest the view of many AEC staff members at the time—the issue of waste form had largely been resolved by appendix F. After all, the Idaho facility had been producing calcined waste for nearly a decade; General Electric had adopted this same process for its proposed reprocessing plant at Morris, Ill. This view seemed so entrenched that, when Milton Shaw, the author of appendix F, severely cut back funds for waste form research at Hanford to save money for the breeder development program, strong objections from the head of AEC's Operational Safety Division were ignored.

This presumed closure on the waste form issue lasted only a few years. Commissioner Larson, an underwater explorer who had seen glass siting undecomposed on the seabed, began to argue that developing "an essentially insoluble solid form for our radioactive high-level waste . . . should be one of the highest priority efforts in our waste management program."[114] Those arguments resonated as it became increasingly clear that the unstated assumption of appendix F, early establishment of a repository, would not be fulfilled. In fact, by 1974, AEC's waste management policy was premised on extended surface storage in the RSSF. The shift in policy direction had to be coupled, AEC's Waste Management Director asserted, with a shift in policy regarding waste form:

> The probability of failure of the RSSF is proportional to the time in storage, and protection against the conse-

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[107] "Siting of Commercial Reprocessing Plants and Related Waste Management Facilities," AEC 180/47, Oct. 9, 1968.

[108] "Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities," SECY-160, July 31, 1970.

[109] "Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities," AEC 180/88, June 17, 1970, p. 29.

[110] App. F required that the liquid waste be converted to a solid form within 5 years after reprocessing and the solid transported to a Federal repository no later than 5 years thereafter. The timing was somewhat arbitrary but represented a balance between waiting for the waste to cool and avoiding large build-ups of liquid waste.

[111] Atomic Energy Commission 180/47, op. cit., p. 5.

[112] Memorandum, Thompson to the other Commissioners, June 22, 1970, p. 3.

[113] Minutes of Commission Meeting 2429, Aug. 8, 1970, pp. 10-11.

[114] Memorandum, Larson to the other Commissioners, June 26, 1972.

> quence of escape during extended surface storage would be enhanced by modifying the waste to a form having a lower probability of dispersal to air (by decreasing the surface to volume ratio) or to water (by decreasing leachability). The probability of dispersion can be decreased by having the waste in a massive low-leachable glass (or ceramic) form while it is in surface storage.[115]

It was recognized that a change in position on the waste form question could have unsettling effects on the emerging reprocessing industry. Thus, the waste management staff recommended that a centralized glassmaking plant be built at the RSSF site by AEC.[116]

Significantly, in neither the public nor internal record is there any consideration of the desirability of the glass waste form in terms of long-range, hundreds of years, safety. Nevertheless, the demise of the RSSF and the proposed Calcine Conversion Facility and a return to an emphasis on geologic disposal did not mark the end of the glass waste form. Only 5 years after it was dismissed by the Director of Regulation, it came to figure prominently in the center of the "Baranowski bull's-eye" which graphically depicted the multiple barrier design or repositories. Waste form, presumably glass, was seen, for the first time, as something more than a modality for moving waste; it had become a means of significantly improving repository performance.[117]

Once waste form was certified as an important potential contributor to long-term safety, it took little time before the choice of glass came under attack. By 1976, borosilicate glass was already being criticized for having too high of a leach rate and for being too subject to devitrification.[118] Within the materials science community, the debate over waste form raged furiously and eventually ignited into controversy over an NAS report on the subject.[119] Behind the technical substance of that debate, however, is a more fundamental policy question: to what degree should waste form and packaging be elevated from the potential contributor to long-term safety to a fully redundant element of a waste management system?

Currently, the staff of DOE maintains that borosilicate glass, while perhaps not the ultimate waste form, is good enough. They believe that other forms would be costly and time-consuming and potentially more hazardous to develop. Those disadvantages would not be outweighed by large gains in long-term system reliability because the geology of a repository can be depended on. The staff of NRC argues that "it would be highly desirable to place major, if not primary, importance on the waste form itself, its packaging, and the local waste-rock interface. This would leave the geology as a fully redundant additional barrier."[120] The regulators' position clearly derives from a more skeptical view of the potential for predicting the behavior of repository systems and geologic formations far into the future. One indicator of the intensity of the NRC position is the fact that in its proposed technical criteria for regulating geologic disposal of high-level radioactive waste only one specific standard is set forth: the performance criteria for the waste package.[121]

Determining Acceptable Safety Levels for a Geologic Repository

In the previous two sections, the discussion has focused on strategies for finding "acceptable" sites for a repository and on the desiderata for an "acceptable" waste form package. We have not considered the process through which acceptable levels of safety are determined and precisely what those levels are. This section will consider how the process of determining what is acceptably safe has evolved over the last 12 years. However, because the process has not yet reached closure, no statement can be made about its outcome. Instead, this section will also explore the implications of developing sites and waste packages absent a final determination of acceptability.

Judgments about acceptability, it must be recognized, are fundamentally matters of preference. Scientific and technical findings can inform those judgments by clarifying what the levels of safety associated with particular system design or repository siting decisions are likely to be. Even if those findings should be consensually accepted as being empirically accurate (no small task in itself), it still remains for the individual or society as a whole to determine, based on a set of values, whether those levels of safety are satisfactory or not.[122] In the final analysis, then, judgments about acceptability cannot be validated or invalidated; they have the same status as questions of taste.

Prior to 1975, no formal process had been set into place to resolve explicitly the issue of acceptable levels of safety. To be sure, an AEC licensing board during the 1960's did grant construction and operating permits to the NFS reprocessing plant at West Valley, N.Y.[123] Implicit in those authorizations was the judgment that the storage of liquid waste in tanks for an indefinite period of time posed an acceptable burden to society. But, pragmatically, the drive to introduce commercial reprocessing totally dominated considerations of the appropriate level of acceptability for managing the waste generated by the facility.

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[115] "Pros and Cons of Alternative Roles of Government and Industry Reconverting High-Level Waste to Glass," SECY-74-673, May 28, 1974, p. 1.

[116] Ibid., pp. 1-2; see also WASH-1539, pp. 2.5-31—2.5-34.

[117] No record can be found pertaining to the origins of this elevation of waste form.

[118] This criticism was first raised in 1976 and was incorporated into the American Physical Society study, op. cit., pp. S128-S132.

[119] See Luther Carter, "Academy Squabbles Over Radwaste Report," *Science* 205, July 20, 1979, pp. 287-289.

[120] Letter, Jack Martin to Sheldon Meyers, June 11, 1979.

[121] *Federal Register*, March 1981.

[122] See, *Report to the President*, Interagency Review Group on Nuclear Waste Management, TID-29442, Washington, D.C., March 1979, p. 42.

[123] A provisional construction permit—CSF-1—was granted Nuclear Fuel Service on Apr. 30, 1963.

The repository proposed for Lyons, Kans., in 1970 provided another instance where a judgment had to be rendered about the site and repository design's acceptability. Because AEC ultimately chose to abandon those plans, no definitive assessment of acceptability was ever made. Nevertheless, the environmental impact statement for the project documents well the logic of how such decisions were made at the time.[124]

Two features of that logic are particularly striking. First, the process for determining the acceptability of a site and repository design was illustrated. Views about what constituted an acceptable social burden were admitted from only a narrowly based segment of the policy. In particular, the value judgment offered by the NAS's Committee on Radioactive Waste Management that "the use of bedded salt for the disposal of radioactive waste is satisfactory" was endorsed and accepted.[125] The views of elected officials in Kansas that the specific project was too risky were discounted.[126] This situation is somewhat ironic because, only 4 years previously, AEC ignored the value judgment of a majority of the NAS Committee that the Savannah River bedrock project was unacceptably hazardous and proceeded with site exploration.[127] Second, because no a priori standards for site suitability were ever explicitly enunciated, even this narrowly based judgment of acceptability could not be held accountable. Selection of a site in the absence of explicit standards for acceptability raised concern in some quarters that AEC would be able to shoot an arrow at a wall, to draw the target around where the arrow landed, and then to pronounce itself an expert marksman.

With the withdrawal of the Lyons EIS in 1972, and with AEC falling back to a strategy of long-term surface storage, a hiatus of activity emerged and, as a result, an opportunity arose to adjust the process by which matters of acceptability might be resolved. No evidence is available which suggests that such an effort was undertaken. The prevailing view within the AEC during that 1972-75 period appears to be that, whenever the time came to develop a repository, judgments about acceptability of a site and a design would be rendered in much that same relatively closed and informal fashion as they had been in the past.

Starting in 1974, however, the process for determining acceptability in waste management began to undergo two fundamental alterations. First, EPA, after years of bureaucratic in-fighting, established a firm toehold in the domain of radiation protection standards. EPA issued standards for the front-end of the nuclear fuel cycle, for reactor operations, and for reprocessing of spent nuclear fuel.[128] In addition, the agency announced it intended to develop standards for the disposal of nuclear waste. Such criteria would, for the first time, impose explicit constraints on repository developments.

The second change was the passage of the Energy Reorganization Act of 1974. That law, which took effect in January 1975, abolished AEC and established in its place ERDA and NRC. The motive behind the legislation's approval was to remove a potential—many believed actual—organizational conflict of interest by separating the development of nuclear power from its regulation. Not surprisingly, then, both the House and Senate bills contained language authorizing NRC to license any "facility used primarily for the receipt and storage [sic] of high-level radioactive wastes."[129] The notion of an independent review of a repository project was one of those proverbial ideas whose time had come. A review of the legislative history of the Energy Reorganization Act finds no record of opposition to this provision—one which represented a major policy shift.

The entry of EPA and the establishment of independent review authority for NRC marked the transition from an informal process of determining acceptability to a formal process of regulation. First ERDA and then DOE would have to choose a site and design a disposal facility that would meet the regulations that NRC promulgated to ensure that EPA's standards would be satisfied. What was and still is indeterminate was how the regulatory role would evolve and mature.

Conceivably, there are a spectrum of approaches under which the regulators might interact with repository developers. At one extreme, the regulators adopt a relatively passive posture. The developers proceed with their efforts absent any regulatory guidance under the implicit assumption that any facility constructed would ultimately have to be accepted by the regulators. Under this approach, regulation would ultimately degenerate into a posteriori approval. At the other extreme, the regulators would establish criteria and standards independently of the developers and compel those responsible for repository siting and design to conform. The developers could proceed only with generic studies until final regulations were promulgated. Mixed approaches might also be adopted. For example, regulation and development could emerge as interactive, iterative, and somewhat informal activities. The developers provide information to the regulators about what is technically possible. Moreover, the developers disregard technical possibilities that seem unlikely to be viewed positively by the regulators. At the same time, the developers pursue designs that allow key parameters to be modified within a range that is likely to include the regulatory standard. Thus, the regulators and the developers work together through the site selection process and up to the time licensing commences.

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[124] Lyons' Environmental Impact Statement, pp. 8-13.

[125] National Academy of Sciences/National Research Council, *Disposal of Solid Radioactive Wastes in Bedded Salt Deposits*, 1970, p. 1.

[126] See Lyons' Environmental Impact Statement, pp. 55-5105.

[127] National Academy of Sciences/National Research Council, 1966, pp. 73-75.

[128] See, *Environmental Analysis of the Uranium Fuel Cycle*, EPA-520/9-73-003, Environmental Protection Agency, Washington, D.C., 1973; and 40 *Code of Federal Regulations* 190.

[129] Energy Reorganization Act of 1976, sec. 202(3).

Settling on a regulatory approach is no easy matter. The first alternative, while the least time-consuming, is almost certainly legally tainted; moreover, political opposition to it would be vocal and intense. The polar extreme, however, is just as problematic. EPA has still to issue its standards, even in draft form. Without those standards, NRC's job of issuing detailed regulations becomes more complicated. In short, if the developers were simply to wait for the regulators to act, substantial unfortunate delays would well result. What is clear today, that neither extreme approach is viable, was sensed back in 1975. Some mixed approach had to be taken. How that course was charted and its implications are the subjects to which we now turn.

All mixed approaches, by definition, entail interaction between the regulators and the developers. What distinguishes one such approach from another, however, is which of the two sides provides the driving force that shapes their relationship and how strong that thrust is. When NRC was first created, it possessed neither the institutional knowledge nor the resources to deal with ERDA on an equal basis. As a result, NRC's regulatory efforts were initially designed to track ERDA's developmental plans. As those plans shifted, however, NRC found itself in the position of having to recast its own priorities. For instance, NRC first concentrated on developing procedures and techniques for regulating the choice of site and designing of repositories in bedded salt. When a domed salt facility became a leading contender, NRC found that it could not develop new regulatory tools in time to meet the deadlines then envisioned.

As NRC matured as an institution, the balance between the regulators and the developers (now DOE), shifted, resulting in changes in the character of the prevailing mixed approach. The publication of NRC's policy statement on licensing procedures for geologic repositories marks one stage in that evolution.[130] The proposed policy called for informal regulatory review of the developers' site selection decision. The NRC staff might provide comments and advice but the Commission itself would not make any formal findings or take any formal action. The developers would be at liberty to proceed as they chose in the face of that guidance. The first formal DOE-NRC interaction would occur prior to the sinking of the repository shaft. NRC could either authorize repository construction if certain findings were made, or it could delay authorization until additional data was obtained from sinking the shaft. Unresolved safety issues might be deferred until construction was completed if it was felt that further research was likely to yield favorable solutions. A second formal licensing review would occur prior to the receipt of radioactive material at the repository. NRC concurrence would also be required at the time of closure and decommissioning.

Implicit in those proposed procedures was a vision of the relationship between regulator and developer. In particular, the NRC staff believed that it was essential for the regulators to intervene formally in the process before substantial organizational and resource commitments to the site had been made by DOE. Absent such early involvement, the regulators faced a risk of being swept along by the developers' momentum. Herein, then, lay NRC's first major effort to assert the initiative in its relations with DOE.

Yet, almost as soon as the proposed policy statement had been issued, the NRC waste management staff, now under new leadership, began to question the policy's logical foundations.[131] In particular, the staff came to believe that any formal authorization prior to the sinking of the shaft, or even after it for that matter, would have to be made on the basis of incomplete and inadequate data. For emerging scientific opinion, articulated by the USGS, NAS, and the President's Interagency Review Group, suggested that "exploration and testing at depth should be performed to determine whether the surrounding geology will retard waste migration."[132] Thus, NRC proposed to require such investigations prior to issuing a permit for constructing a repository.

This shift increased the risk of premature commitment and the concomitant pressures such a commitment might generate. Recognizing that NRC might lose the initiative in dealing with DOE, the revised procedural regulations adopted new strategy: "To guard against DOE's making a premature and preemptive commitment to a particular site in a particular medium . . . this [revised] approach provides for characterization of a number of sites at different locations and in different media."[133] Thus, a multiple-site strategy not only emerges as the one seemingly most consistent with the realities of geologic understanding, but it is also an effective means of asserting regulatory control over the actions of the developers.

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[130] *Federal Register* 43, Nov. 17, 1978, pp. 53869-53872.

[131] *Federal Register* 44, Dec. 6, 1979, pp. 70408-70421.

[132] Ibid., p. 70410.

The evolving shift in the force driving the relationship between the regulator and the developer can also be observed in the proposed technical criteria issued by NRC in 1981.[134] Three examples stand out as being particularly striking in this regard. The first is the requirement that the waste package contain radionuclides completely for 1,000 years. The second is the extensive discussion given to the problem of human intrusion. The third is the clear signal that alternative waste forms and packages be investigated. None of these requirements appear to be at all arbitrary or constitute an abuse of regulatory discretion. Yet each could also reasonably be interpreted as a technical maneuver designed to force DOE to retrofit its program to conform with the regulator's desires. Certainly part of DOE's negative reaction to the 1,000-year waste form requirement could be viewed in this light. Moreover, NRC's strong concern about the issue of human intrusion has to be understood in the context of the controversy over the Waste Isolation Pilot Plant site. In that instance, DOE appeared ready to proceed despite the presence of amounts of potash in the area that might prompt exploration and exploitation in the future. Finally, the dictum about alternative waste forms and packages must be read in the light of the criticism NRC has made about the adequacy of the DOE program.

The developmental program has continued to expand even as the relationship between NRC and DOE evolved. And not unexpectedly some costs have been paid because of this. Perhaps the most significant one has occurred in the realm of site selection. Absent formal regulatory guidance, DOE has had to develop its own selection criteria. Although they have made a serious effort to accomplish that task responsibly,[135] it does seem clear that resource and organizational commitments have been made to sites that might not conform to NRC's selection criteria or satisfy NRC's procedural requirements for choosing sites for characterization. In the view of some observers the process for selecting the sites is flawed and further work on them merely undermines public confidence in the program.[136]

The Relationship Between the Federal Government and the States in Nuclear Waste Management

The Federal Government and several States can possess overlapping jurisdictions and share powers. In the field of nuclear waste management, the Federal Government through NRC has entered into agreements with a number of States whereby the latter entities regulate the activities of low-level waste burial grounds.[137] Current law specifies that the States take over this responsibility fully through the formation of regional compacts.[138] In the domain of high-level waste disposal, however, Federal law, at least at this time,* does not authorize and probably precludes the sharing of power and authority. Nevertheless, successful implementation of a high-level disposal plan requires that the States be intimately involved. For behind a formal lack of State power lies a plethora of informal powers that must be accommodated. The accommodation is necessary because the States firmly believe that they must protect the unique interests of those residing within their jurisdiction.

In this section, we shall examine how Federal officials responsible for waste management began by discounting the informal authority of the States, believing that it would not be exercised, and ended up conceding to the States formal powers that legally could not be rendered.

AEC's involvement with the States dates back to the earliest days of the waste management program. At that time, AEC worked closely with local health officials and sanitary engineers in the design of facilities to store waste from the military program. By 1956, AEC was consulting with State and interstate public health and water pollution control agencies and was involving State governments in the evaluation of geological and hydrological problems associated with disposal of liquid and solid waste. Moreover, a continuing dialog was reported to be taking place on the waste management issue through such mechanisms as AEC's Advisory Committee of State Officials and the Council of State Governments. One analysis for AEC observed that this Federal/State interaction had been quite positive and recommended that it be continued and strengthened. Yet, the analysis concluded, that relationship could prosper only if it "rested on information derived from sound research and development programs integrated with knowledge and appreciation of the experiences of . . . communities in resolving their . . . environmental problems."[139]

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[133] "Proposed New 10 CFR Part 60—Disposal of High Level Radioactive Wastes in Geologic Repositories—Procedural Aspects," SECY-79-580, Oct. 22, 1979, p. 6.

[134] *Federal Register,* March 1981.

[135] See, *NWTS Criteria for the Disposal of Nuclear Wastes: Site Qualification Criteria,* ONWI-33(2) (Columbus, Ohio: Battelle, 1980).

[136] See some of the critical comments on the siting choice and the Department of Energy's response to them in *Final WIPP EIS,* DOE/EIS-0026, 1980.

[137] The Agreement States authority is found in the Atomic Energy Act of 1954, as amended, sec. 274.

[138] See Low Level Waste Management Policy Act of 1980, which passed Congress on Dec. 13, 1980.

*Prior to passage of the Nuclear Waste Policy Act of 1982.

Over the next decade and a half, the character of the Federal/State relationship did not significantly change. Then, as noted above, in 1969, a fire broke out at AEC's military facility at Rocky Flats, Colo. Considerable quantities of plutonium-contaminated debris were produced. The material was shipped to the waste storage grounds at the National Reactor Test Station (NRTS) in Idaho. Concerned about NRTS's role as a "dumping ground," Idaho Senator Frank Church requested a multiagency investigation of the facility's operations and environmental impacts.[140] Although the subsequent report clearly indicated that AEC's practices in Idaho fully protected the health and safety of the State's population,[141] Church, backed by Governor Cecil Andrus, pressed for a commitment from AEC to remove the wastes and dispose of them elsewhere.[142]

AEC recognized that such an action was consistent with its evolving waste management policy. Even before the Rocky Flats fire, AEC had moved toward an approach for commercially generated waste that centered on the use of Government-owned repositories. It was certainly feasible to use those planned facilities to dispose of the transuranic contaminated waste stored at Idaho. Thus, AEC Chairman Seaborg agreed to honor Church's request and promised to begin removing the waste by 1980.[143] That commitment marked the first time a State had substantively affected the direction of AEC policy. The States' role had clearly expanded beyond providing technical collaboration.

It is ironic that AEC's sensitivity to—or at least a pragmatic recognition of—the concerns of the States in the case of Idaho directly influenced its decision to undertake the Lyons project, an endeavor which since has come to be viewed as so lacking both in sensitivity and pragmatism with regard to the State of Kansas.[144] Earlier in this paper the technical issues that cast a shadow over the project's viability were noted. It is important to recognize that as the exploration and characterization of the site progressed, the political atmosphere was quite turbulent as well.

In the decision memorandum the Commissioners approved authorizing the Lyons project, explicit directions were given to the staff to "consult with State officials."[145] The written historical record is unclear about the scope of those consultations. Nonetheless, it is likely that members of the Kansas Geological Survey and probably the staff of the Governor's office and of local legislators were briefed. What we do know is that no unambiguous commitments of political support for the project by the State emerged from those consultations. AEC had not "lined up its ducks" at the time of the public announcement on June 17, 1970, that Lyons had been tentatively selected as the first repository site.[146]

AEC's politically exposed position made it more vulnerable to first the skepticism and then the criticism of U.S. Congressman Joseph Skubitz, who represented a Kansas district which did not include Lyons. Skubitz began by asking a straightforward question: why had the Kansas salt fields been selected rather than a site in the Salina basin that would have been closer to the operating and planned reprocessing plants in New York, Illinois, and South Carolina? The agency responded by saying the Kansas site possessed "geologic characteristics . . . generally more favorable than those of the salt in the Salina basin." AEC furthermore justified the long transport routes to Kansas by postulating a reprocessing plant in California; that hypothetical plant would then make Lyons a centrally located spot.[147]

AEC's answer to Skubitz was misleading in that it emphasized the technical bases for the choice and virtually ignored the nontechnical factors.[148] The site selection process, as we noted above, was less than systematic; the analysis supporting the choice of Lyons took up less than eight pages. Yet, even the analysis concluded that Lyons enjoyed, at best, only a marginal technical advantage over other potential sites. If anything, the Kansas salt mine was chosen because of local acceptance of the experimental Project Salt Vault and because AEC did not want to wait for—nor did it have the resources to fund—an investigation of other locations.[149] All this is not to say that AEC's choice was wrong; simply it was less than candid in dealing with one Representative from Kansas.

AEC also had difficulty in answering specific technical questions raised by Skubitz with the obvious help of Kansas Geological Survey's new director, William Hambleton. Concerns were raised about the thermal effects of the geological system, about the problem of brine inclusion, about the available techniques for borehole plugging, about possible mechanisms for retrieving the waste if necessary, and about the potential for radiation damage to the salt. Many of these same concerns were held by AEC and NAS. But because AEC had only skimpily funded waste management research and development, very few definitive studies could be cited to bolster the agency's claim that the site was sound.

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[139] Atomic Energy Commission 180/5, op. cit., p. 14.

[140] Letter, Church to Seaborg, Sept. 13, 1969.

[141] Letter, Bureau of Radiological Health to Church, February 1970.

[142] Letter, Church to Seaborg, Apr. 30, 1970.

[143] Letter, Seaborg to Church, June 9, 1970.

[144] For an example of such a view, see H. Peter Metzger, *The Atomic Establishment* (New York: Simon & Schuster, 1972), pp. 154-160.

[145] Atomic Energy Commission 180/87, op. cit., p. 6.

[146] Atomic Energy Commission Press Release, N-102, June 17, 1970.

[147] Letter, Erelwine to Skubitz, June 11, 1970.

[148] Atomic Energy Commission 180/87, op. cit., pp. 4, 16.

[149] Atomic Energy Commission 180/81, op. cit., pp. 4-6.

Instead, AEC pointed to work under way to resolve many of those issues and, in essence, sought to hold the debate in abeyance until the research reached fruition. Skubitz, however, strongly argued that it was inappropriate to select a site, even tentatively, absent those technical findings. For him, AEC's decision to proceed with work at Lyons was both a premature commitment and an act of faith, a faith he did not share.

In the months after the project was publicly announced Skubitz was in the forefront of the attack. Other Kansas officials seemed to adopt a wait-and-see attitude. That was not to last for long. Spurred on by AEC's seeming lack of candor, disturbed by the agency's underdeveloped technical program, and irritated by what they saw as AEC's patronizing and arrogant manner, other local officials soon joined the fray. By the beginning of 1971, Governor Robert Docking had become a firm opponent of the Lyons project, and began to question AEC's motives and good faith.[150] Eventually, in August 1971, both of Kansas' Senators, Robert Dole and James Pearson, sponsored an amendment to AEC's authorizing legislation prohibiting buying of land or burying waste materials at Lyons until such time as an independent advisory council, appointed by the President, reported to Congress that the establishment of a repository and burial of high-level waste could be carried out safely.[151] Thus, AEC's inability to satisfy the not altogether capricious concerns of State officials resulted in their losing considerable autonomy in implementing a major policy decision in waste management.

The Lyons experience had a profound effect on AEC and its successor agencies. While the RSSF was being planned, AEC engaged in intensive consultations with State officials from Nevada, Idaho, and Washington. And although State concerns were not completely resolved, intense confrontations never broke out as they did over the Kansas project.

By the time the RSSF was canceled and as ERDA reinvigorated efforts aimed at finding new sites for a geologic repository, nuclear energy policymakers clearly recognized that States had to become more intimately involved in waste management decisionmaking. Thus, in November 1976, ERDA's Administrator, Robert Seamans, wrote to State governors and legislators to inform them of the agency's plans to expand the site exploration program. The letter offered to work closely with the States and to keep the Governors informed of how the efforts were progressing. Most significantly, Seamans committed himself to terminating a project within a State "if the State raises issues . . . connected with [technical] criteria and their application that are not resolved through mutually accepted procedures."[152] The States, in effect, were being offered at least the potential of a veto over the construction of a waste facility within their jurisdiction.

The response of State officials was mixed. Some, such as those representing South Carolina, Kansas, Michigan, and Wisconsin, wrote to Seamans and explicitly disinvited ERDA from even exploring potential repository locations. Others, such as those representing New York, Missouri, and Colorado, were reluctant to welcome ERDA until further studies, such as the Generic Environmental Impact Statement on Waste Management, were completed. Finally, still others, such as those representing Oklahoma, Missouri, Mississippi, and Louisiana, did agree to work with ERDA to develop ground rules which might permit site exploration to proceed. No State, however, evinced much enthusiasm and one by one States soon were dropped from consideration. Thus, what began as a new initiative, a fresh start in the area of waste management, soon got mired down in the reluctance of State officials even to contemplate a facility on their soil.[153]

The expanded exploration program was directed at finding sites for disposing of commercially generated waste. A parallel effort to construct a repository in New Mexico for military waste had, as we noted above, been in progress since 1973. State officials and local influentials had initially welcomed the possibility of utilizing a site near Los Medanos for a Waste Isolation Pilot Plant (WIPP).[154] By 1978, surface-level site characterization was well under way. And a correspondingly mature institutional relationship had evolved between the Federal and State Governments. The New Mexico Governor established a Radioactive Waste Consultation Task Force, an Environmental Evaluation Group, and an Advisory Committee on WIPP. Those groups carried out independent evaluations and assessed the technical validity of the characterization program and provided advice to the Governor. DOE funded a substantial fraction of that State effort.

Cooperation between the two levels of government was further facilitated by an informal agreement that provided the State of New Mexico with the right of concurrence on the construction of any facility proposed for the long-term permanent disposal of nuclear waste. The State interpreted that right to include the opportunity not to concur and on a number of occasions Federal officials acquiesced in that interpretation. Another factor which cemented the Federal/State partnership was the commitment from the Carter administration in 1978 that WIPP would be licensed by NRC.[155] Such an independent formal review process would help satisfy New Mexican concerns that the facility was indeed "safe."

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[150] See Letter, Dockings to Skubitz, Feb. 20, 1970, for first hints of Docking's growing opposition.

[151] See proviso inserted in AEC Authorizing Legislation for fiscal year 1972 for item 72-3-b, the proposed Lyons repository, op. cit.

[152] Letter, Seamans to State officials, Nov. 26, 1976, p. 3.

[153] *Report of Task Force*, op. cit., p. 12.

[154] Gourmley, op. cit., pp. 3-5.

By all accounts, then, as the 1970's drew to a close, DOE and New Mexican officials had established fundamentally strong working relations that were able to survive such occasional shocks as periodic shifts in the proclaimed functions WIPP would fulfill and disagreements over the adequacy of the draft WIPP impact statement.[156] In December 1979, however, Congress passed the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980. That law was reluctantly approved by President Carter, who at the time of the signing expressed strong disagreement with the legislation's provisions affecting WIPP. In particular, the bill undermined the basis on which New Mexico's cooperation rested: it prohibited DOE from granting the State a veto over the construction of the facility and prevented its licensing by NRC.[157] Once again, DOE found its relations with a key State strained almost to the breaking point.

DOE's relationship with the States had developed in an ad hoc fashion over the last half of the 1970's. By early 1978, it became clear to many policymakers that that interaction had to be formalized and institutionalized. DOE began intensive consultations with the leadership of the National Governor's Association (NGA). NGA adopted a resolution in August 1978 which asserted that DOE had to "obtain State concurrence prior to final site determination."[158] At precisely the same time, President Carter's Interagency Review Group on Nuclear Waste Management (IRG) was formulating the concept of "consultation and concurrence." Under that approach, the "State would be in agreement with each step in the [repository development] process before the next activity" would begin.[159] The IRG formulation was ambiguous, perhaps purposely so. Six months later, IRG recast and clarified the concept. In particular, a distinction was made between consultation and concurrence and a State veto. The former, it was held, implied a continuing dialog between the States and the Federal Government; the latter suggested an action taken only at one discrete point in time.[160] To many, IRG's distinction was without a difference: the obverse of concurrence was nonconcurrence, which was pragmatically equivalent to a State veto. Nevertheless, this formulation of consultation and concurrence made explicit a policy that had been informally pursued for several years; it also proffered more power to the States than they were, up to that time, legally entitled to.

The formalization by the executive branch of this policy raised two questions, neither of which has been definitively answered. The first question focused on the wisdom of granting the States the ability to delay or defer a critically needed national effort. Indeed, President Carter seemed to retreat from the recommendations of IRG when he emphasized the "consultation" phase and deemphasized the "concurrence" phase in his waste management policy statement.[161] Moreover, several Members of Congress expressed concern that DOE had gone too far in trying to satisfy the States' demands, thereby creating a dangerous precedent for the future.[162] Even some State executives indicated that they did not welcome the power not to concur. To have such authority, in their view, would virtually compel them to use it.

Yet, those who opposed endowing the States with substantive controlling influence over repository siting were probably in the minority. For the majority the real issue—and the second question raised by DOE's policy—was how would the modalities of the process be designed. In particular, what steps could the Federal Government take if it disagreed with a State's nonconcurrence? President Carter created by Executive order a State Planning Council (SPC) composed of Governors, legislators, and representatives of Indian tribes, to provide advice on issues such as that.[163] SPC resolved that, in case of disagreement between DOE and a host State, the latter could only be overridden by an explicit Presidential determination supported by both Houses of Congress.[164] When Congress itself took up the issue in late 1980, both Houses agreed on an override mechanism for commercial high-level waste disposal: the host State would only be sustained if either the House or the Senate affirmatively concurred with the State's position.[165] Congress, however, could not agree on the right of a State to object to a facility designed to dispose of defense high-level waste. In fact, the disagreement was largely responsible for Congress' inability, at that time, to pass a bill dealing with high-level waste.

Linking Reactor Operation With the Development of Techniques for Radioactive Waste Disposal

> . . . the general problem of radioactive waste need not retard the future development of the nuclear energy industry with full protection of the public health and safety.[166]

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[155] Confidential interviews with author, 1978.

[156] Ibid., 1980.

[157] Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Sec. 213, 93 Stat. 1259.

[158] *Nuclear Energy Policy Position*, op. cit., adopted August 1978.

[159] *Report to the President*, TID-28817 (draft), Interagency Review Group on Nuclear Waste Management, Washington, D.C., p. 52.

[160] *Report to the President*, final report, op. cit., pp. 88-96.

[161] Presidental Statement on Nuclear Waste Management Policy, Feb. 12, 1980.

[162] See, for instance, letter, Dingell to O'Leary, Apr. 21, 1978.

[163] Executive Order No. 12192, Feb. 12, 1980.

[164] State Planning Council Resolution No. 4-10.

[165] See, S.2189, sec. 908, 96th Cong., for example.

[166] *Industrial Radioactive Waste Disposal*, op. cit., p. 3.

That statement gives expression to a particular logic. It holds that as long as a solution to radioactive waste disposal is clearly envisioned, there is no need to prevent the commercial nuclear industry from developing and maturing. Another logic can also be constructed. This one holds the generation of nuclear waste, particularly by the commercial nuclear industry, ought to be linked to a resolution of the problem of waste disposal. Which logic prevails depends strongly on the outcome of activities in the legal and political arenas. In this section, one will examine how those outcomes have made the linkage logic more salient although not dominant.

Throughout the period when AEC existed, Congress and the President implicitly sanctioned the development of a nuclear power industry unconstrained by the status of the waste management program. For a dozen years, 1959-71, one can find fewer than 25 pages of testimony about any aspect of radioactive waste management amongst the many thousands of pages reporting on hearings held by the JCAE on commercial nuclear power.[167] Two reports addressed to the President on civilian nuclear power mentioned the unresolved waste disposal question, but there is no evidence that President Kennedy, President Johnson, or their staffs saw in that unsettled issue any reason for concern.[168] Moreover, during that 1959-75 period, the nuclear industry contracted for all but six of the reactors ordered in this country.[169] Such a large financial commitment ensured that the industry's political clout would be used to oppose any action linking reactor deployment with progress in waste disposal.

AEC behaved in a fashion consistent with the incentives and signals provided by its political environment. The agency's policymakers and operating personnel rarely even entertained the idea that, as the waste management program lagged behind reactor development and deployment, the latter effort should be slowed until the former effort reached fruition. When they did consider the issue of linkage, it was always quickly dismissed. For example, a 1965 memorandum to Commissioner Ramey reaffirmed the validity of the conclusions adopted by the JCAE without offering any further analysis or rationale.[170]

By the early 1970's, however, AEC recognized that its political environment had changed somewhat. A memorandum prepared for an AEC policy session noted that "the uncertainties concerning location of the repository are already adversely affecting public acceptance of nuclear power, and it is possible that this aspect of the overall nuclear program could become an unnecessarily important negative factor in the Nation's ability to consider its nuclear option to power generation."[171] At about the same time, the agency also recognized that the National Environmental Policy Act required the consideration of the environmental effects of the uranium fuel cycle, including waste management, in reactor licensing hearings.[172] A year later, a staff analysis of waste management policies noted that any major changes in AEC's programs "might be used by nuclear opponents as an indication that nuclear waste cannot be handled safely for the long term and that nuclear power should be halted."[173] But if perceptions of and demands from the political environment had begun to change, agency behavior did not. For example, AEC staff argued that the S-3 table, which quantified the environmental effects of the fuel cycle, need not even be considered because, "if factored into individual cost-benefit analyses, [it] would be sufficiently small as not to affect significantly the resultant conclusion."[174] When it came time to prepare the first programmatic environmental impact statement on commercial waste management, AEC did not analyze the option of shutting off reactors pending progress in the waste disposal program; to have addressed that option would have been in its view too time-consuming.[175]

The tenor of the political environment, however, shifted dramatically in 1976. In June, the State of California passed a bill which conditioned siting of reactors within the State on a finding that "the United States through its authorized agency has proved that there exists a demonstrated technology or means for the disposal of high-level nuclear waste."[176] When such a finding could not be made, a de facto moratorium on new nuclear reactors began in the State.[177] Although the law was overturned as an unwarranted intrusion in an area preempted by the Federal Government,[178] the fact that a powerful actor—the State of California—had firmly rejected the logic of JCAE was not lost.*

In a separate action, scarcely a month after the California Legislature had acted, the Court of Appeals for the District of Columbia invalidated the rule which was supported by the S-3 table.[179] Powerplant certification was abruptly halted and remained so for 2 months. More significantly, by holding that AEC had failed to develop the technical analysis for the rule adequately, the court became the first Federal institution to demand that a reasoned response and analysis of the consequences of waste disposal techniques be provided before additional reactors could be brought on-line: "Once a series of reactors is operating, it is too late to consider whether the wastes they generate should have been produced, no matter how costly and impractical reprocessing and waste disposal turn out to be; all that remain are engineering details to make the best of the situation which has been created."[180] In effect, the court's opinion, while not mandating either logic, did reinforce the arguments of those seeking an explicit linkage between reactor operation and demonstrable techniques for waste disposal.

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[167] See footnote 8 in *NRDC* v. *Nuclear Regulatory Commission*, 547 F. 2d 633 (1976) (Hereinafter NRDC v. NRC).

[168] See, for example, *Civilian Nuclear Power—A Report to the President, 1962*, U.S. Atomic Energy Commission, Washington, D.C., 1962. The brief section on waste management appears on pp. 54, 55.

[169] *The Nuclear Industry-1974*, WASH-1174-74, U.S. Atomic Energy Commission, Washington, D.C., 1975, pp. 8-13.

[170] Pittman to Ramey, op. cit., p. 1.

[171] SECY-2271, op. cit., p. 2.

[172] *Federal Register* 37, Nov. 15, 1972, pp. 24191-24193.

[173] "Policies for Management of Commercial High-Level Radioactive Waste," SECY-74-222, Nov. 16, 1973, p. A18.

[174] *Federal Register*, 1972, p. 24192.

[175] *Nuclear Fuel Cycle*, ERDA-33, Energy Research and Development Administration, 1975, p. 47.

[176] California Public Resources Code 255 24.2, West Supp. 1977.

[177] California Energy Resources Conservation and Development Commission, *In the Matter of Implementation of Nuclear Reprocessing and Waste Disposal Statutes*, No. 76-NL-1, 76-NL-3, Jan. 25, 1978, p. 5.

[178] *Pacific Legal Foundation, et al.* v. *State Energy Resources Conservation and Development Commission*, reported in CCH, *Nuclear Regulations Reports*, pp. 16, 621-16, 628.

*The law was ultimately upheld by the Supreme Court in 1983.

In November 1976, the environmental litigating group, the Natural Resources Defense Council (NRDC), petitioned NRC to conduct a rulemaking proceeding "to determine whether radioactive wastes generated in nuclear power reactors can subsequently be disposed of without undue risk to the public health and safety and to refrain from acting finally to grant pending or future requests for operating licenses until such time as this definitive finding of safety can be and is made."[181] By this petition, NRC was being asked to reconsider the logic that had guided Federal regulatory and developmental programs for 17 years. NRC denied the petition the following June. In the explanation of its denial, the Commission maintained that it was not obligated, under the Atomic Energy Act, to make the determination requested by NRDC.[182] That claim was later sustained in court.[183]

But in denying the petition, NRC did not reject the logic of linkage. It did state that "it would not continue to license reactors if it did not have reasonable confidence that the waste can and will in due course be disposed of safely."[184] That statement advanced two critical policy innovations and was made at the insistence of the Chief of the Waste Management Branch over the objections of the Executive Legal Director. The first innovation was the distinction between "can and will." That distinction marked a departure from the posture of technological optimism. Second, the Commission's explanation for its confidence was based on and tied to the general direction taken by both NRC and ERDA programs at that time. "The clear implication is that if the direction of the present program[s] should change significantly, NRC as a matter of sound policy may no longer be in a position to continue licensing reactors."[185]

The California laws, judicial review of the S-3 table, and the NRC response to the NRDC petition all left profound and depressing impressions on those defending the logic of the Joint Committee. Mustering their forces, those opposing linkage did prevail in the intense and bitter bureaucratic infighting over the Carter administration's proposals for reforming reactor licensing procedures. Advocates of including a specific linkage provision found their views rejected by the President himself. The opponents of linkage were also heartened by the Deutch Report's recommendation to dispose of 1,000 spent fuel rods at the WIPP, a recommendation many believe was prompted by a desire to satisfy California's law.[186] Moreover, the President's Interagency Review Group managed to avoid the question of linkage in preparing its analysis.[187] Yet despite these events, forces within the Government still pressed for a commitment to nuclear power which was dependent on progress in waste disposal. For example, one such advocate, J. Gustave Speth, formerly a lawyer for NRDC and later a member and then Chairman of the Council on Environmental Quality (CEQ), announced, to the surprise and shock of many colleagues, that CEQ favored "a national decision which would make the expanded use of nuclear power contingent on a clear and convincing showing, after consideration of both technical and institutional factors, that nuclear power's deadly byproducts can be safely contained for geologic periods."[188]

Additional pressures to establish an explicit linkage between reactor licensing and the resolution of the waste management question began to mount in May 1979, when the District of Columbia Court of Appeals ruled in the case of *Minnesota* v. *NRC*.[189] The plantiffs challenged NRC's licensing decision in two cases in which utilities sought to expand their onsite capacity for storing spent fuel. The plaintiffs argued that, absent a proven waste management system, the environmental effects of continued at-reactor storage for an indefinite period of time into the future had to be considered. Moreover, they argued that unless the analysis demonstrated an acceptable level of environmental impact, the additional storage space could not be constructed. While the NRC Licensing Appeal Board accepted the logic of the plaintiffs' contentions, it held that the Commission, in its denial of the NRDC petition, had resolved the issue by stating that it had reasonable confidence that safe methods of permanent disposal would be available when needed.[190] The court, however, felt that such a pivotal statement had to have a firmer analytical foundation than the Commission had thus far provided. The court, therefore, remanded the case to the agency for further consideration in "the interest of sound administration."[191] In October, NRC announced its intention to conduct a generic processing "to reassess its degree of confidence that radioactive waste produced by nuclear facilities will be safely disposed of, determine when any such disposal will be available, and whether such wastes can be safely stored until they are safely disposed of."[192] That proceeding, to which there are over 40 parties, is expected to conclude in 1983.

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[179] *NRDC* v. *NRC*, op. cit.

[180] Ibid., p. 637.

[181] Petition is printed in *Federal Register* 42, Jan. 13, 1977, p. 2730.

[182] "NRDC Petition for Rulemaking on Waste Management," SECY-77-48B, June 1, 1977.

[183] *NRDC* v. *NRC and United States of America*, reported in CCH, Nuclear Regulation Reports, pp. 16537-16544.

[184] SECY-77-48B, attachment 1, p. 14.

[185] SECY-77-48B, op. cit., p. 2.

[186] Confidential interviews with author, 1978; also see *Task Force Report*, op. cit., pp. 16-17.

[187] *Report to the President*, final report, op. cit., pp. 5-8.

[188] Quoted in the *New York Times*, Sept. 30, 1977, p. 12.

[189] *Minnesota* v. *Nuclear Regulatory Commission*, 602 F. 2d 412 (1979).

Coping With Interdependence

As the reader is undoubtedly aware, the eight elements of waste management policymaking just presented are not independent of each other. Rather, events transpiring in one sphere affect and constrain later events in all spheres. In this penultimate section, first introduced is a conceptual framework for understanding those interactions; it then is employed to explicate the intricacies of waste management policymaking.

At the outset of this paper, developing the nuclear power energy system was a rather complex task laden with uncertainties. Also noted were those characteristics of complexity and uncertainty that led policymakers to assign a low organizational priority to the issue of waste management up until 1975. Now there is a need to explore further some of the implications of complexity; this time the complexity of the waste management domain itself.

Although there is some disagreement about the concept's meaning among those who use it, the level of complexity will be associated with the number and richness of the interdependencies that join the components or elements of a policy domain. A policy domain will be complex if it possesses a large number of interdependencies among its elements and if it is structured in a fashion that prevents breaking it down into relatively self-contained systems capable of being treated independently of each other. In engineering phraseology, complexity is what distinguishes tightly coupled from loosely coupled systems. In cybernetic terms, complexity results from the presence of numerous feedback channels. Complexity is what forces econometric modelers to abandon a system of recursive equations and shift to a system of equations that capture a series of reciprocal relations. While no convenient metric exists which scales complexity, a persuasive case can be made that the nuclear waste management policy domain is relatively complex. In figure A-2, the major interdependencies among the domain's elements are sketched out.

Most of those relationships can be inferred from the analysis of the eight elements of policymaking. The choice of waste form is dependent on whether spent fuel rods or high-level reprocessed byproducts are considered to be waste. But the choice is also determined by how adequate the scientific/technological knowledge base is deemed to be. For instance, those who are skeptical of our current ability to engage in accurate long-term predictions of geologic behavior would choose more sophisticated forms than those who had more confidence. Moreover, regulatory standards, such as the proposed technical criteria recently suggested by NRC, have an obvious influence on the waste form selected. In a similar manner the choice of siting strategy will depend on the adequacy of the knowledge base; the greater the uncertainty, the more redundant the strategy is likely to be. But the siting strategy will also be strongly affected by the requirements of the National Environmental Policy Act as well as specific mandates of NRC such as its licensing regulations.

The capability to develop a system for disposing of radioactive waste will be a function of the siting strategy, the choice of waste form, the adequacy of the scientific/technological knowledge base, and the thoughtfulness and sophistication of the implementation program. That latter component subsumes, among other things, logistical and budgetary planning, manpower training, designing responses to large changes of scale in operation, and post-decommissioning monitoring. Capability will be influenced as well by the regulatory standards set forth by NRC and EPA; the stricter the standards, the less likely, ceteris paribus, will be the existence of sufficient capability to meet them.

But in an important way, those regulatory standards are also affected by capability. If the regulators, for instance, do not believe that a requirement for zero release for 10,000 years is within the current or near-term projected capability, they will be reluctant to impose it. The standards will be influenced by elements in the regulators' political environment such as courts, Congress, and by the outcomes of battles among competing interest groups as well.

Like beauty, however, capability is often in the mind of the beholder. Those perceptions will not be independent of some "objective" assessment of the development act but they will be influenced—perhaps strongly—by

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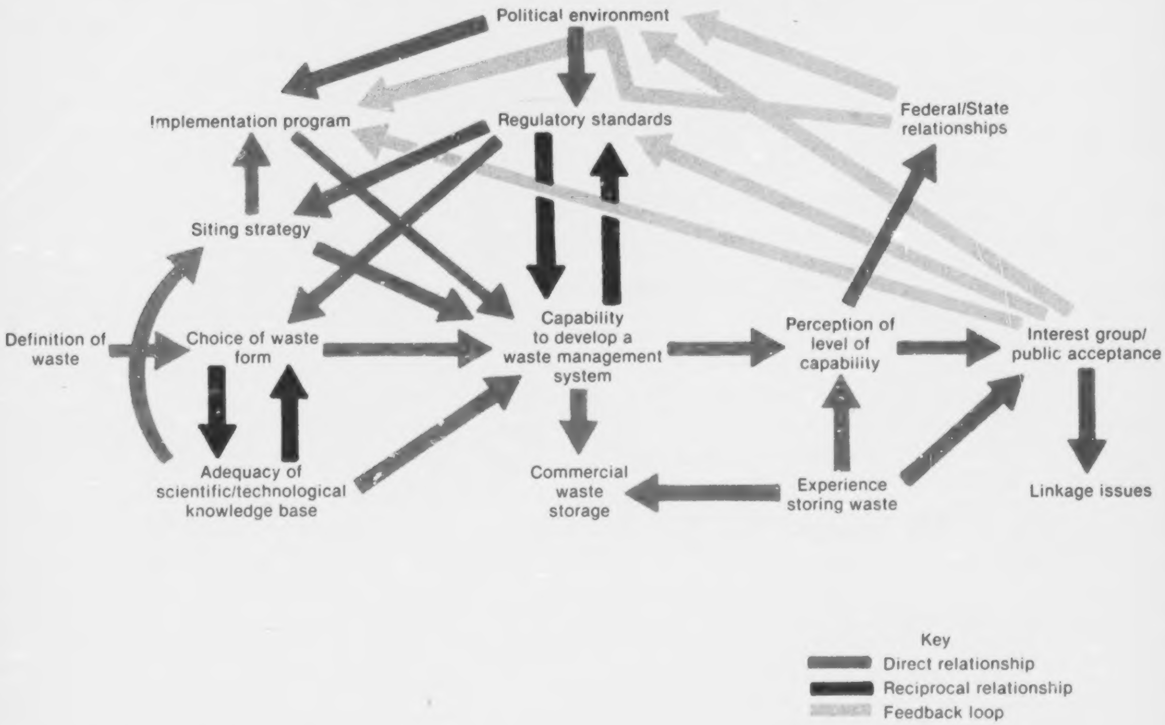
[190] 7 *NRC* 51.

[191] *Minnesota* v. *Nuclear Regulatory Commission*, 418.

[192] *Federal Register* 44, Oct. 25, 1979, pp. 61372-61375.

Figure A-2.—Waste Management Policymaking


Political environment
Implementation program
Regulatory standards
Federal/State relationships
Siting strategy
Definition of waste
Choice of waste form
Capability to develop a waste management system
Perception of level of capability
Interest group/ public acceptance
Adequacy of scientific/technological knowledge base
Commercial waste storage
Experience storing waste
Linkage issues
Key
Direct relationship
Reciprocal relationship
Feedback loop

other factors as well. For instance, the historical experience of waste management will affect an individual's sense of current capability. Totally exogenous considerations such as political philosophy, value orientation, or lifestyle may also play a role in evoking perceptions of capability.

This distinction between capability and perceptions of it is not a trivial one: for it is the latter factor, not the former one, which directly influences other elements in the policymaking schema. In particular, the activities of interest groups are premised on their particular views about capability. Members of the general public will accept or reject proposed projects based on their beliefs about capability. Moreover, Federal/State relationships will develop in ways determined by perceptions of capability; the less favorable the perceptions, the greater the effort subordination jurisdictions will make to have a strong say in waste management decisionmaking. Finally, those perceptions will affect how salient the linkage issue is likely to be; unfavorable beliefs increase sensitivity to the claim that waste is being produced without any demonstrated means at hand to dispose of it.

These interactions among elements of the waste management policy domain dynamically play themselves out over time. Thus, the definition of waste accepted at time T affects the choice of waste form at time T + 1. In similar fashion, the degree of public acceptance for a particular project or policy at one point in time influences the character of the political environment at some later point. Finally, the reciprocal relationship between choice of waste form and the adequacy of the knowledge base and between regulatory standards and capability can also be understood in terms of a time-lagged interdependence.

The dynamism, critically conditioned by the complexity of the domain, engenders important consequences as policymaking unfolds. Any given element comes to depend in a nonsimple manner on prior states of a range of other elements. Not only need policymakers concern themselves about managing a set of direct relationships, but they also must address a set of indirect ones as well. In less formal terms, the dynamism and complexity of policymaking quickly locks the elements of the domain together. Past decisions and performance come to influence and constrain present choices in important respects. Four examples can illustrate how this process has occurred.

Example One

Adequacy of knowledge → Capability → Perceived capability → Acceptance

So long as all the major actors in waste management policymaking subscribed to the salt assumptions, consensus prevailed as to the general adequacy of the scientific/technological knowledge base. The clear implication of that consensus was that isolating waste was a quite solvable problem. Certainly that was the thrust of the earliest NAS study. Those not directly involved had no basis for questioning that claim and, thus, overall perceptions of capability were positive. Interest groups and the general public, to the extent they even thought about the issue of waste, were quiescent.

As the consensus began to dissolve in the mid-1970's, questions were raised about capability—with some arguments being advanced that isolation, in principle, was impossible Within the larger community, perceptions about capability grew more skeptical. As those perceptions became more widespread, they provided the basis for opposition among interest groups and members of the public.

In short, actions taken early on in the history of waste management severely constrained the options available in later years. As the premises which underlay action shifted, the nuclear developers found themselves locked in, unable to respond to changing circumstances without undergoing considerable organizational trauma.

Example Two

Adequacy of knowledge → Capacity → Regulatory standards → Waste form

The erosion of the consensus about salt, undermining faith in the elegant solution, had additional consequences beyond activating interest groups and members of the general public. Personnel at both EPA and NRC began to ponder what their response should be. At both organizations, skepticism replaced confidence in the accuracy of predictions of geologic behavior over long periods of time. The simple and straightforward assumptions held in the past were seen to be inadequate.

Although EPA's position cannot be ascertained, since the agency has not promulgated its draft standards and criteria, NRC's response has been strikingly clear. Those regulators have mandated that the waste form and package become fully capable of isolating the waste independently of the repository and surrounding environment. In other words, given the inadequacy of knowledge and the resulting predictive uncertainties prudence requires that the repository geology not be the sole barrier preventing release of the waste. The waste form and package must maintain its integrity for over 1,000 years. After that, the waste must not escape beyond the engineered portion of the repository at a rate of greater than 10^{-5} per year.

Example Three

Perception → Federal/State relationships → Political environment → Implementation

In the early 1970's, when AEC embarked on the Lyons project, the view was widely held among leaders of the Kansas Geological Survey that insufficient knowledge about repository design had been gathered. The men from Kansas pointed to what they felt were primitive heat-flow models as well as gaps in understanding waste-rock interactions and rock mechanics. These concerns about the technical viability of the effort provided a basis for opposition on the part of U.S. Representative Skubitz and Governor Docking.

Those officials unleashed a barrage of criticism on AEC, and despite the agency's best effort, those protests—asserting that State interests were being ignored—never diminished. Within a year, the controversy had escalated. Kansas Senators Dole and Pearson were persuaded to introduce an amendment to an AEC authorization bill. The rider required that an expert advisory committee be appointed to certify that the Lyons site was sound and the repository design was reliable. Absent such certification, the Commission could not proceed. Had the effort gone ahead, the agency would have lost its autonomy over the project's implementation.

Example Four

Experience with storage → Perception → Federal/State relationships → Political environment → Implementation

Historically, it has been the case that people's judgments about the degree of capability have, rightly or wrongly, been strongly influenced by the record established in storing waste from the military program. Images of leaking tanks at Hanford and the orphaned waste at West Valley subvert claims of competence for disposal. As the images became more widespread and as the waste issue became more salient, State officials began to seek Federal guarantees that would ensure that any project within a State would be predicated on a high level of scientific and technical expertise.

Without those assurances, States were reluctant even to permit repository site investigation, let alone actual site selection. As more and more States espoused that position, a new-era "tragedy of the commons" loomed.

The National Governors' Association, in response, advanced the idea of consultation and concurrence and soon found it accepted by the Carter administration. Formal agreements were to be negotiated between the States and DOE which would govern the implementation of further repository development activity.

The complexity and dynamic nature of the waste management policy domain—characteristics we have tried to lay out conceptually and with help of the four examples just presented—are not merely intellectual abstractions. Rather, the existence of those two features has some significant real world implications.

First, if our arguments are valid, the past is indeed prologue; the slate can never be wiped clean. Actions taken in the past continue to reverberate within the domain of waste management policymaking. To be sure, the impact of those actions—unless reinforced by later similar ones—becomes attenuated as they recede in time. But the impact never disappears completely. Thus, present day policymakers find themselves saddled with a not-entirely-welcome legacy. Although they may assert that the "time has come to put Lyons behind us," they are indulging themselves if they believe that can easily happen. Past problems will reside in the consciousness of many players.

The most salient consequence of this pertains to the problem of credibility. Even the most objective and scientifically responsible and competent DOE program managers will find that they will be judged not only on their own merits but on their predecessors' as well. The claim that "things will now be done right" will often appear hollow in the face of a string of past failures and incomplete successes. Altering that perspective will not be a trivial undertaking.

A second implication of the complexity and dynamism of the waste management policy domain follows from the first. At this point in time, 35 years into the nuclear age, there is only limited room for new failures in dealing with those toxic materials. Certainly, the current program is substantially improved in terms of resources, broader organizational commitment, and sophistication compared to the one in place as recently as 5 or 6 years ago. A sense prevails that progress—albeit slow progress in some people's view—is being made. Yet, the optimism is fragile. There simply is not much "slack" present. Should a glaring error arise, there will be little or no residuum of good will to buffer the program from profound shocks.

Conclusions

On the basis of the discussion in the preceding 10 sections, a range of conclusions can be drawn about how waste management policymaking has evolved over time. For ease of presentation, the findings will be categorized as follows: conclusions about the policymaking process; conclusions about the technical basis for policymaking; conclusions about problem-solving strategies; and conclusions about the institutional dimension of policymaking.

The Policymaking Process

Up until approximately 1975, waste management and particularly waste disposal efforts were fragmented from and subordinate to other aspects of nuclear development. That state of affairs was an expectable organizational response to uncertainty and complexity. Waste management and disposal was funded at low levels; the problem had low bureaucratic visibility; research and development directed toward disposal was quite rudimentary.

Waste management policies have shifted frequently over the years. Initial plans to construct a repository at Lyons, Kans., had to be abandoned in 1972. AEC then pursued a policy of extended surface storage until 1975. Those efforts were replaced by a program emphasizing disposal in salt formations. More recently, the program has looked at an expanded range of potential candidate sites in a variety of geologic media.

Major waste management policies were made on an incremental and ad hoc basis. The waste management program has lacked a unified guiding philosophy that could lend coherence to decisionmaking. Policymaking has tended to be reactive rather than proactive. It has often had a short-term rather than a long-term orientation.

Difficulties encountered in one sphere of waste management have often created problems in other spheres. Developing a waste disposal system requires the fine tuning of a number of interdependent components. When difficulties arose in one sector, they carried over into other parts of the system. As a result, problem-solving was retarded in a wider number of areas.

Waste management policymaking retains little slack to buffer against additional setbacks. Many of those involved in the waste management policy domain hold the view that the program has been relatively unsuccessful. Those negative images have damaged the program's credibility. In many quarters, no residuum of good will exists to mitigate the shock of some new policy failure.

Technical Issues

Although uncertainties over some technical questions persist, no one has suggested that waste disposal in geologic formations is, in principle, not possible. Many technical issues remain unresolved. Disagreements remain about the significance of those issues and corresponding policy consequences. Nevertheless, throughout the history of waste management problem-solving, no credible argument has emerged which undermines the feasibility of geologic disposal.

After an initial overwhelming emphasis on disposal in salt formations, attention has increasingly been given to candidate sites in other media. For many years, AEC, heavily influenced by NAS, was committed almost exclusively to finding a site in salt. Not until the mid-1970's did ERDA expand the range of potential host formations. DOE has broadened even further investigations and research into sites other than salt.

Although more is known about engineering a repository in salt, no particular host geologic formation enjoys a preferred status as a potential disposal site. Geologic knowledge has evolved since the early 1950's when salt was recommended as the preferred disposal media. A technical consensus has emerged which holds that the repository and its hydrogeologic environment must be analyzed in tandem to ensure the isolation of the waste. Once that environment has been factored into disposal design, most geologists believe that suitable sites can be found which utilize a wide variety of host rock formations.

Waste forms and packages have evolved from being mere conveniences to becoming fully redundant components of a disposal system. The attention paid to waste form early on was mainly directed at increasing the ease of transportation of the material from a reprocessing plant to the repository. Later, ERDA advocated other waste forms that would increase the middle term isolation capability of a disposal system. In 1981, NRC issued a proposed regulation that elevates waste form and packaging into a major component whose performance strongly affects the very-long-term isolation capability of the system.

Strategic Issues

Until 1978, the strategy for seeking disposal locations focused on a single site at a time; no site intercomparisons were to be made prior to site selection. Personnel at AEC and ERDA adopted this strategy of single site investigation in part because they had to operate on tight budgets. They also saw no reasons why comparing sites offered any safety advantage. Current NRC procedural regulations, however, require some site intercomparison prior to the issuance of a repository construction permit.

A single site strategy can be politically risky. The nuclear developers must operate in a political atmosphere characterized by suspicion and skepticism. No jurisdiction is enthusiastic over the prospect of being a host for a repository. If only one site is under active consideration at a time and no alternative exists, that suspicion and skepticism becomes reinforced and local opposition intensifies.

Nontechnical considerations have played an important initial role in selecting sites to date. It is largely immaterial whether technical or nontechnical factors are considered first in choosing a potential repository site so long as both can exert an unbiased influence in the process. Tentative site selection in Kansas and in New Mexico relied heavily at the start on nontechnical factors. Concerns were raised in each case that technical considerations were not given their appropriate weight.

Institutional Issues

The definition of waste, whether it includes spent fuel as well as high-level reprocessed waste, has important implications for decisions about storage and disposal. Historically, the waste management program had presumed that reprocessed waste would be disposed of. As that assumption came under challenge and was undermined, adjustments—some of which were major—had to be made in the program. The current waste management program seeks to avoid those difficulties in the future by designing facilities that will accommodate either reprocessed waste or spent fuel rods.

Repository development has been complicated by the absence of regulatory standards. The nuclear developers have proceeded over the years to design repositories and investigate potential sites without much regulatory guidance. This has had two consequences: first, emerging regulations have forced the developmental program to make time-consuming and costly adjustments. Second, the developmental program encountered public suspicion and skepticism because its internal standards and criteria were unaccountable.

Policies predicated on extended storage have enjoyed acceptance only when coupled with strong commitments to and implementation of a credible program of disposal. The Federal Government has advocated long-term waste storage on at least four different occasions. Each time public criticism has been intense. Only when the plans for storage were linked to a well-funded disposal program did the opposition become somewhat attenuated.

Federal/State relationships have evolved with the States being given a more active role in waste disposal policymaking. Initially the State role was one of technical collaboration. State concern over repository siting decisions coupled with their informal powers to delay Federal effort augmented that role. Current policy with regard to commercial waste disposal envisions a major State contribution in siting choices.

Pressures to establish a formal linkage between further generation of commercial waste and progress to-

ward solution of the disposal problem have grown over the years. Prior to 1975, there were very few who advocated that linkage. Thereafter, however, a number of States adopted laws conditioning further growth in nuclear generating capacity on a resolution of the waste issue. NRC is currently holding hearings to determine its stance on the question.

In this paper, the major themes and issues in the history of waste management policymaking have been detailed. By understanding the successes and failures that marked that history, people might in the future avoid policies that are error-prone. Therein lies the potential contribution of this research.

Appendix A-2
Major Events in Waste Management History—1944-81

INTRODUCTION

This appendix provides summary descriptions of the major events in high-level radioactive waste management from 1944 to 1981. Each event is organized and referenced according to its role in one of four major areas of historical interest: development of long-term (interim) storage, disposal options, high-level regulations, and Federal waste management structure and responsibilities. Table A-2 at the end of this section displays parallel time lines for the events in each of these four areas, with the reference numbers for each event shown in the proper time sequence.

PART I

Development of Long-Term (Interim) Storage

THE HANFORD EXPERIENCE

Reference: I-A1—December 1944

Construction of the first storage tanks for high-level liquid radioactive waste is completed at the Hanford Reservation. The material that is put into those tanks came from reprocessing reactor fuel irradiated to produce the plutonium, some of which ultimately was used in the bomb that destroyed Nagasaki, Japan. The single-walled tanks were constructed out of carbon steel that was less durable, but more readily available and less expensive than stainless steel. The life expectancy of the tanks was estimated to be between 50 and 100 years. The use of carbon steel tanks required that the acidic liquid waste streams be made alkaline.

Reference: I-A2—January 1952

Operations begin at the Redox reprocessing plant. This new chemical process for extracting plutonium from irradiated reactor fuel rods produces a significantly smaller volume of waste than did the original bismuth phosphate. Because of the greater concentration of fission products in the waste stream, however, the liquid waste from the first-cycle extraction system is self-boiling and must be stored in tanks with appurtenances for boiling waste. These tanks are still constructed of single-walled carbon steel and the waste is made alkaline prior to storage.

Reference: I-A3—January 1956

Operations begin at the large capacity Purex reprocessing plant. This new chemical process for extracting plutonium further reduces the volume of waste produced. The waste are still self-boiling and are stored in similarly designed single-walled carbon steel tanks.

Reference: I-A4—July 1958

The first leak of 55,000 gallons (gal) was detected in a tank containing nonboiling waste constructed in 1944. The leak was remedied and did not endanger the public as far as could be determined.

Reference: I-A5—March 1965

In order to reduce the number of new tanks to handle the waste from new production and to replace some old tanks, the Atomic Energy Commission (AEC) and the operators at Hanford embark on an in-tank solidification program. The purpose of this program is to reduce the liquid to a salt cake that would remain in the tanks even if cracks developed. The first waste to be solidified were those in the Y-tank farm and were nonboiling waste.

Reference: I-A6—June 1967

Because of their higher heat content, self-boiling waste could not be solidified in their tanks. To immobilize those wastes, AEC and the Hanford operators begin waste fractionation. In this process, the long-lived, high heat generating fission products, cesium and strontium, are removed and the remainder of the waste is allowed to decay until it can be evaporated in tanks to a salt cake and sludge.

Reference: I-A7—February 1971

First double-shell waste storage tanks available for use at Hanford. The new tanks consist of a freestanding carbon steel tank inside a steel-lined reinforced concrete vault; a tank within a tank. This design provides secondary containment of the waste. Any leakage from the primary tank would be detected and corrective actions taken before any radioactive material comes in contact with the surrounding soil. The primary tank is also heat treated after fabrication (stress relieved) to prevent stress corrosion cracking believed to be the cause of previous tank leaks.

Reference: I-A8—May 1973

The largest leak occurs in the 106-T tank constructed in 1947. Over 100,000 gal of waste is released because the operators failed to monitor the liquid levels in a receiving tank during transfer from one tank to another. The leak was remedied and did not endanger the public as far as could be determined.

Reference: I-A9—November 1973

The waste Encapsulation and Storage Facility begins operation. This facility takes the separated cesium and strontium and packages the isotopes in a form that allows for their ultimate disposal. Until that time, the packages are stored in an engineered facility and cooled by circulating water.

THE SAVANNAH RIVER EXPERIENCE

Reference: I-B1—November 1954

High-level liquid waste is first generated at the Savannah River Plant as part of the military production program. The waste results from reprocessing irradiated reactor fuel using a modified Purex process. The self-boiling waste is made alkaline and stored first in single-walled carbon steel tanks. Later on, double-walled carbon steel tanks are constructed and used at Savannah River.

Reference: I-B2—October 1957

The first tank leak is detected at Savannah River but none of the material is released into the environment.

Reference: I-B3—March 1960

AEC and the operators of the Savannah River Plant begin an in-tank solidification program which, like the one at Hanford, reduces the waste to a dry salt cake and sludge.

THE IDAHO EXPERIENCE

Reference: I-C1—February 1953

Reprocessing of irradiated fuel from AEC's experimental reactor program and the Navy's nuclear fleet begins at what is now the Idaho National Engineering Laboratory. The waste streams are not neutralized but are instead stored in stainless steel tanks.

Reference: I-C2—December 1963

The acidic waste are solidified by means of a fluidized bed waste calcinator facility for the first time. The liquid waste is sprayed into a bed of calcine which is agitated by a flow of hot air and heated to the calcining temperature. The product is converted to granular solids which are pneumatically transported to storage facilities.

Reference: I-C3—May 1970

A fire at an AEC-owned weapons fabrication facility located at Rocky Flats, Colo., leaves considerable solid waste contaminated with transuranic material. The facility ships the waste for storage to the Idaho facility, Idaho's Governor and Senators protest the transfer and receive a pledge from AEC Chairman Seaborg that the waste will be removed by the end of the decade.

Reference: I-C4—October 1976

Construction begins on a new waste calcining facility to convert liquid high-level waste to a granular solid. The new facility will replace the older calcining facility, which was designed as a demonstration unit, and it will provide many operational improvements.

NUCLEAR FUEL SERVICES REPROCESSING OPERATION

Reference: I-D1—May 1963

After years of effort to encourage commercial ventures in fuel reprocessing AEC approves a construction permit for the Nuclear Fuel Services Corp. (NFS) to build such a facility in West Valley, N.Y., NFS adopts the Savannah River model of liquid waste storage in tanks. New York State Atomic Development Authority agrees to be responsible for safeguarding the waste and for maintaining the tanks in perpetuity. NFS pays into trust fund for the care of the waste.

Reference: I-D2—April 1966

NFS receives an operating permit and commences fuel reprocessing.

Reference: I-D3—March 1972

NFS ceases operation and closes down for remodeling and expansion. During its nearly 6 years of operating, the company reprocessed 160 metric tons of fuel from the commercial nuclear power industry and 480 metric tons of fuel from the military production reactors at Hanford. A total volume of 640,000 gal of uranium processing waste are stored in mild steel tanks and 12,000 gal of acid thorium waste are stored in stainless steel tanks.

Reference: I-D4—April 1976

The Getty Oil Co., current owners of the NFS facility, announces their withdrawal from the reprocessing business and request that New York State, in accordance with its 1963 agreement, take over responsibility for the liquid waste stored in tanks.

Reference: I-D5—July 1979

The Energy and Water Development Appropriation Bill for 1980 directs the Department of Energy (DOE), using funding provided to it for commercial waste management, to provide necessary technical support to study and recommend a nuclear waste solidification program at West Valley, N.Y., and to assist the State of New York as appropriate in developing such a program. Based on this direction, DOE initiates studies and announces its intent to prepare an environmental impact statement (EIS) on alternatives for solidification of the high-level liquid waste in storage at the NFS site.

THE RETRIEVABLE SURFACE STORAGE FACILITY

Reference: I-E1—June 1972

AEC announces plans to construct an engineered retrievable surface storage facility (RSSF) to hold commercially generated high-level waste until the time when a geological repository is available for waste disposal. This initiative is prompted by the failure of the Lyons repository project. The RSSF would be essentially designed as mausolea and would be sited at large AEC or Federal sites in the sparsely populated portions of the Western United States.

Reference: I-E2—September 1974

AEC issues an EIS in support of the RSSF. The EIS draws critical comments from a wide range of groups and individuals including some Western Governors and the Environmental Protection Agency (EPA).

Reference: I-E3—April 1975

The Energy Research and Development Administration's (ERDA) Administrator Seamans, in one of his first official acts, withdraws the RSSF impact statement and requests that the proposed congressional authorization for the RSSF be deleted.

SPENT FUEL POLICY

Reference: I-F1—April 1977

President Carter announces that, in pursuit of nonproliferation objectives, his administration would seek the deferral of commercial reprocessing and associated recycle of plutonium. Under this policy, spent fuel would become the waste form of the future.

Reference: I-F2—October 1977

DOE, with Presidential approval, announces a spent fuel policy which has three major components. First, the administration will construct a large away-from-reactor facility to store any spent fuel that utilities wish to transfer to the Government. The Government would then take title to the fuel and have responsibility for it until it is permanently disposed of. Second, at the time of transfer, the utilities would pay a one-time charge for the Government's services. The charge would fully pay for storage as well as disposal costs. Third, the United States would accept for storage and disposal limited amounts of foreign spent fuel if such an action would contribute to this country's nonproliferation objectives.

Reference: I-F3—March 1981

The new Reagan administration declines to continue efforts to construct an away-from-reactor storage facility.

PART II

Development of Disposal Options

GENERIC STUDIES AND INVESTIGATIONS

Reference: II-A1—August 1957

The National Academy of Sciences (NAS) Committee, providing advice to AEC, reports on the possibility of disposing radioactive waste in geological formations. The Committee is convinced that "radioactive waste can be disposed of safely in a variety of ways and at a large number of sites in the United States." The Committee also maintains that "disposal in salt is the most promising method for the near future." Furthermore, the Committee notes that "disposal could be greatly simplified if the waste would be gotten into solid form of relatively insoluble character." Significantly, the Committee observes that "the necessary geologic investigation of any proposed site must be completed and the decision as to safe disposal means established before authorization for reactor construction is given. Unfortunately, such an investigation might take several years and cause embarrassing delays in the issuing of permits for construction. This situation can only be handled by starting investigations now of a large number of potential future sites as well as the complementary laboratory investigations of disposal methods."

Reference: II-A2—February 1959

The Joint Committee on Atomic Energy (JCAE) holds hearings on Industrial Radioactive Waste Disposal. Scores of witnesses from Government, industry, the national laboratories, and academia testify and present scientific papers on the manifold aspects of radioactive waste storage and disposal. The hearings led AEC and JCAE to conclude that: 1) radioactive waste management practices have not resulted in any harmful effects on the public, its environment, or its resources; and 2) the general problem of radioactive waste need not retard the future development of the nuclear energy industry with full protection of the public health and safety.

Reference: II-A3—November 1962

In a report to President Kennedy on civilian nuclear power, AEC maintains that the waste management problem is "technically soluble" and that "aside from the central reactor development program proper, no other phase of the entire program is more important than that of waste disposal."

Reference: II-A4—March 1971

JCAE returns to the subject of waste management and conducts extensive hearings on the proposed repository in Lyons, Kans. Following those hearings, the Committee reports out an authorization bill providing funds for the facility. The implementation of the project is conditioned upon a finding by an advisory committee, appointed by the President, that "the establishment and burial of high-level waste can be carried out safely."

Reference: II-A5—January 1972

AEC publishes the first version of its plan for managing waste generated as part of the defense program. The plan details AEC intentions for short- and long-term storage of liquid high-level, low-level, solid, and gaseous waste.

Reference: II-A6—May 1974

AEC publishes its first technical analysis of potential alternative methods for long-term management of high-level radioactive waste. The document is based on reports written for AEC by the Battelle Pacific Northwest Laboratory. Neither the Battelle report nor the AEC summary reaches any conclusion about a preferred disposal option.

Reference: II-A7—November 1975

JCAE holds its first oversight hearings specifically on the waste management question since 1959. The Committee hears reports from the program managers of ERDA, the Nuclear Regulatory Commission (NRC), and EPA.

Reference: II-A8—May 1976

ERDA releases the so-called Technical Alternatives Document (TAD) which describes the technologies available for managing radioactive waste from commercial nuclear power. TAD updates and expands the analyses reported by Battelle 2 years previously. Like its predecessor, TAD makes no evaluation of the competing technologies nor does it reach any policy-relevant conclusions. Work on TAD was undertaken in response to a request from JCAE. The document was also required to provide technical support for the preparation of a Generic Environmental Impact Statement on Commercial Radioactive Waste Management (GEIS).

Reference: II-A9—October 1976

ERDA publishes a proposed Table of Contents for its GEIS and requests public comment.

Reference: II-A10—April 1979

After undertaking one major version of the document, DOE publishes a draft version of its GEIS. The impact statement is intended to support a programmatic decision to concentrate, in the near term, on mined geological repositories as a means for waste disposal.

Reference: II-A11—October 1980

DOE publishes final version of the GEIS.

Reference: II-A12—July 1977

The U.S. Geological Survey (USGS) releases Circular 770, "Geologic Disposal of High-Level Radioactive Wastes—Earth Sciences Perspectives." Although expressing confidence that "acceptable geologic repositories can be constructed," the circular's authors did conclude that "the earth-science problems associated with disposal of radioactive waste are not simple, nor are they completely understood." The circular noted "many weaknesses in geologic knowledge" particularly with respect to disposal of waste in salt.

Reference: II-A13—January 1978

The American Physical Society (APS) released its study on the nuclear fuel cycle and waste management. The APS group affirms that "effective long-term isolation for spent fuel high-level or transuranic waste can be achieved by geologic emplacement." Moreover, the group concludes that "many waste repository sites with satisfactory hydrogeology can be identified in the continental United States in a variety of geologic formations. Bedded salt . . . can be a satisfactory medium for a repository, but certain other rock types, notably granite and possibly shale, could offer even greater long-term advantages."

Reference: II-A14—February 1978

DOE completes a major internal review of its waste management programs. The reviewers urge expansion of the Department's technical efforts in the area of geologic disposal, maintain that reprocessing is not required for the safe disposal of commercial spent fuel, recognize that a repository for commercial waste may not be ready by 1985, and reaffirm the principle that the responsibility for ultimate disposal of radioactive waste must rest with the Federal Government.

Reference: II-A15—March 1978

President Carter establishes an Interagency Review Group on Nuclear Waste Management (IRG) composed of representatives from 14 governmental units. The group is instructed to formulate recommendations for an administration policy with respect to long-term management of nuclear waste and supporting programs to implement this policy.

Reference: II-A16—October 1978

The draft IRG report to the President is released for public comment along with a Subgroup Report on Alternative Strategies for the Isolation of Nuclear Waste. The draft Presidential report drew heavily on the analysis of the Subgroup report and its appendix which assessed the status of knowledge with regard to geological disposal. In the draft Presidential report, all 14 agencies agree that: the waste disposal program should proceed on the assumption that the first disposal facilities for high-level waste will be in mined repositories; site characterization work in a variety of geological environments should be accelerated; funding should be increased for near-term technical alternatives to geologic disposal; initial placement of waste in a repository should be done on a technically conservative basis and should permit retrievability; and opportunities should be pursued, if available, to site a licensed intermediate-scale facility in which as many as 1,000 spent fuel rods or waste canisters would be emplaced with the possibility but not necessarily the expectation of their removal. The agencies disagreed about the strategy to be employed in choosing sites to be submitted for licensing and on the future of the proposed Waste Isolation Pilot Plant (WIPP).

Reference: II-A17—February 1980

President Carter announces his administration's comprehensive waste management policy. He ratifies all the unanimous IRG recommendations. He resolves the two controversial issues of site selection strategy and WIPP. He decides to adopt a siting approach in which four to five sites in a variety of environments are characterized extensively before a license application for one of them is submitted to NRC. The President also decides to recommend to Congress the termination of the WIPP project.

INVESTIGATIONS IN SALT

Reference: II-B1—November 1965

Following over 3 years of preparation, the first canister of Experimental Test Reactor (ETR) irradiated fuel is emplaced in the abandoned Carey salt mine in Lyons, Kans. This initiates the main phase of Project Salt Vault. The project is designed to determine the thermal and radiation effects of high-level waste on salt and to demonstrate waste handling techniques. The project is carried out by personnel from the Oak Ridge National Laboratory.

Reference: II-B2—June 1967

The last canister of ETR fuel is removed from the abandoned salt mine, thereby ending the experimental phase of Project Salt Vault.

Reference: II-B3—May 1966

NAS reviews AEC's waste management program once again. It reaffirms its 9-year-old view that "salt beds as permanent storage sites for high-level radioactive solids has promise of being successful and satisfactory." The Committee also strongly supports efforts to solidify high-level waste.

Reference: II-B4—June 1970

AEC announces that a site in the salt deposits near Lyons, Kans., had been "tentatively selected" for the country's first repository. The choice is contingent on confirmatory tests being carried out.

Reference: II-B5—July 1970

Political opposition to the repository begins to develop in Kansas with Congressman Joseph Skubitz and Governor Robert Docking taking the lead. They are supported in their opposition by the new head of the Kansas Geological Survey, William Hambleton.

Reference: II-B6—November 1970

The NAS Radioactive Waste Management Committee issues a report on the suitability of the Lyons site. The Committee deems the site "satisfactory" but withholds final judgment pending the completion of additional studies. That additional research would focus on understanding the uniformity of the salt beds, developing techniques for plugging nearby oil and gas wells and boreholes, refining methods of backfilling to prevent subsidence in the salt, and understanding the thermal and mechanical properties of key geologic structures.

Reference: II-B7—September 1971

The AEC program manager for the Lyons repository returns to Washington from a trip to Kansas persuaded that newly discovered technical difficulties severely threaten the project's future. The difficulties involve the discovery of numerous, previously unknown, oil and gas wells and boreholes. These might not be successfully plugged. In addition, water used to solution mine salt in a neighboring mine had "disappeared." This event seemed to suggest that the geological integrity of the proposed site might be inadequate.

Reference: II-B8—February 1972

AEC abandons plans for a repository at Lyons citing technical uncertainties and problems in political and public acceptance.

Reference: II-B9—May 1974

After searching by USGS for over 2 years for a new potential repository site in bedded salt, ERDA decides to begin site characterization at a location outside of Carlsbad, N. Mex. The agency intends this to be a WIPP which would be used to dispose of transuranic contaminated waste, most of which is stored at Idaho, and up to 1,000 canisters of high-level defense waste.

Reference: II-B10—February 1978

An internal agency review of DOE's waste management program recommends that the pilot plant's mission be expanded to include disposal of up to 1,000 commercial spent fuel assemblies and that it be licensed by NRC.

Reference: II-B11--October 1978

DOE issues a draft EIS in support of the WIPP project.

Reference: II-B12—February 1980

President Carter attempts to terminate the WIPP project.

Reference: II-B13—June 1980

Congress overrules the President on the WIPP termination.

Reference: II-B14—September 1980

DOE issues the final EIS for WIPP.

INVESTIGATION OF THE BEDROCK FORMATIONS AT SAVANNAH RIVER

Reference: II-C1—June 1958

The Du Pont Co., the operator of the Savannah River Project under contract to AEC, suggests that the possibility of disposing of the partially crystallized high-level waste in the bedrock underneath the facility be studied.

Reference: II-C2—May 1966

After nearly 6 years of intermittent review of the bedrock proposal, a majority of the NAS Radioactive Waste Management Committee calls the project "dangerous and not worth sinking the exploratory shaft." A minority calls for continuation of experiments and sinking the exploratory shaft, a view which AEC adopts several months later.

Reference: II-C3—October 1970

AEC announces that work would proceed on selection of the bedrock site and on the design of the shaft and exploratory tunnels.

Reference: II-C4—September 1972

The NAS Committee issues a report in which it now concludes that there was a reasonable prospect that the waste could be safely contained in bedrock vaults.

Reference: II-C5—November 1972

AEC decides to abandon the bedrock project, citing technical uncertainties and political opposition of South Carolina Senator Hollings.

EXPANSION OF THE PROGRAM FOR GEOLOGICAL DISPOSAL

Reference: II-D1—February 1972

AEC contracts with USGS to undertake a study of possible sites in salt formations that might be suitable for a repository. The USGS investigation is expanded several years later to include sites in formations other than salt.

Reference: II-D2—October 1975

ERDA policymakers decide to embark on a multiple-site strategy which would lead to the development of several repositories by 2000. The first two of those would be in salt formations; the others might be in other geological media. Letters are sent to 36 State Governors informing them of these plans and asking their cooperation in site exploration activities.

Reference: II-D3—October 1976

Because reactions from many State executives were quite negative and because permission to explore was often denied, the multisite program is forced to retrench. It also suffers budget cuts in the Office of Management and Budget. Site investigations do commence in Texas, Louisiana, Mississippi, Washington, and Nevada.

PART III

Development of High-Level Waste Regulations

NUCLEAR FUEL SERVICES REPROCESSING OPERATION

Reference: III-A1—May 1963

After years of effort to encourage commercial ventures in fuel reprocessing, AEC approves a construction permit for NFS to build such a facility in West Valley, N.Y. NFS adopts the Savannah River model of liquid waste storage in tanks. New York State Atomic Development Authority agrees to be responsible for safeguarding the waste and for maintaining the tanks in perpetuity. NFS pays into a trust fund for the care of the waste.

Reference: III-A2—April 1966

NFS receives an operating permit and commences fuel reprocessing.

Reference: III-A3—March 1972

NFS ceases operation and closes down for remodeling and expansion. During its nearly 6 years of operation, the company reprocessed 160 metric tons of fuel from the commercial nuclear power industry and 480 metric tons of fuel from the military production reactors at Hanford. A total volume of 640,000 gal of uranium processing waste are stored in mild steel tanks and 12,000 gal of acid thorium waste are stored in stainless steel tanks.

Reference: III-A4—April 1976

The Getty Oil Co., current owners of the NFS facility, announce their withdrawal from the reprocessing business and request that New York State, in accordance with its 1963 agreement, take over responsibility for the liquid waste stored in tanks.

GENERAL ELECTRIC REPROCESSING OPERATION

Reference: III-B1—December 1967

AEC grants a construction permit to the General Electric Corp. to construct a commercial reprocessing facility at Morris, Ill. The plans for the facility call for the conversion of cooled liquid high-level waste into a solid form using a calcination process. In 1974, the company decides not to seek an operating permit because of the design flaws in the plant's maintenance systems.

ADOPTION OF APPENDIX F

Reference III-C1—August 1970

After over a year of consideration, AEC adopts appendix F to its regulations (10 CFR 50). The impetus behind the adoption comes from Milton Shaw's Reactor Development and Technology Division. Commissioner Ramey is a strong supporter of the regulation. Both the Production Division and the Division of Industrial Participation express reservations. Commissioner Thompson dissents on the final vote. Appendix F requires that the reprocessed high-level liquid waste be converted to a suitable solid form within 5 years after their production, that the solidified waste be transferred to a repository within 5 years after conversion, and that the repository be operated by the Federal Government and located on Federal land.

ALLIED GENERAL NUCLEAR SERVICES REPROCESSING OPERATION

Reference: III-D1—December 1970

AEC grants a construction permit to the Allied General Nuclear Services Corp. to construct a commercial reprocessing facility at Barnwell, S.C. The Barnwell facility never receives an operating license and is mothballed pending a decision to resume commercial reprocessing.

DEVELOPMENT OF URANIUM FUEL CYCLE RULE

Reference: III-E1—November 1972

AEC announces that it will hold hearings on the environmental impact of the uranium fuel cycle. The purpose of the hearings would be to help formulate a rule that would quantify the annualized impacts arising from the operation of a 1,000-MW reactor. Those impacts would then be considered as part of the required National Environmental Policy Act analysis undertaken when reactors are licensed.

Reference: III-E2—April 1974

AEC issues its rule on the environmental effects of the uranium fuel cycle. The purpose of the hearings would be to help formulate a rule that would quantify the annualized impacts arising from the operation of a 1,000-MW reactor. Those impacts are quantified and presented in the S-3 Table. Almost immediately thereafter, several environmental and public interest groups challenge the rule in court.

Reference: III-E3—July 1976

The U.S. Court of Appeals for the District of Columbia overturns the S-3 rule in *National Research Defense Council (NRDC)* v. *NRC*. The court holds that AEC's consideration of the environmental effects of fuel reprocessing and waste management was not adequately supported by the formal record. Reactor licensing is brought to a halt.

Reference: III-E4—October 1976

After 3 months of intensive effort, NRC publishes a supplement to AEC's analysis of the environmental effects of the uranium fuel cycle. The supplement provides a more complete and thorough consideration of the effects of reprocessing and waste management. At the same time, NRC publishes a proposed interim rule and modifications of the S-3 Table. The interim rule is adopted in March 1977. Preparations are made to hold hearings which will lead to the adoption of a final rule. Reactor licensing is resumed.

Reference: III-E5—April 1978

The Supreme Court reverses the Court of Appeals in *NRDC* v. *NRC*. The Supreme Court holds that the Appeals Court incorrectly imposed more extensive participatory requirements on AEC than were required by the Administrative Procedures Act. The Supreme Court takes no position on the substantive issue of the adequacy of the S-3 Table.

Reference: III-E6—August 1979

NRC adopts a final version of Table S-3 with Commissioners Bradford and Gilinsky dissenting. The Commission recognizes that some explanatory material is necessary to interpret the long-term, cumulative effects of the fuel cycle. NRC also accepts the need to put the health effects in some more easily understood context. Work begins to formulate that explanatory material.

DEVELOPMENT OF PLUTONIUM RECYCLE RULE

Reference: III-F1—August 1974

AEC publishes a draft EIS on mixed oxide fuel, Generic Environmental Statement on Mixed Oxide Fuels (GESMO), and a proposed rule to specify the conditions under which commercial reprocessing and the recycling of plutonium might be permitted.

Reference: III-F2—December 1977

NRC announces that, in response to President Carter's request, commercial reprocessing and plutonium recycling will be deferred indefinitely; it is terminating its GESMO hearings. As a result, commercial nuclear waste takes on the form of spent fuel rather than solidified reprocessing waste.

DEVELOPMENT OF THE TRANSURANIC WASTE RULE

Reference: III-G1—September 1974

AEC announces a proposed rule which would require that all material contaminated with transuranic elements at a concentration of greater than 10 nanocuries per gram be disposed of at a Federal repository. The Commission uses the RSSF EIS as a vehicle for supporting the rule.

Reference: III-G2—April 1975

ERDA withdraws the RSSF impact statement. The withdrawal leaves the rule in limbo.

Reference: III-G3—September 1979

NRC releases a study on waste classification specifying five types of waste: Class A—waste destined for a repository; Class B—waste which must be administratively controlled after disposal at intermediate depths; Class C—waste which can be buried at intermediate depth without administrative control; Class D—waste which can be disposed of by shallow land burial coupled with administrative control; Class E—waste which can be disposed of by shallow land burial without administrative control.

PASSAGE OF ENERGY REORGANIZATION ACT

Reference: III-H1—October 1974

Congress passes the Energy Reorganization Act of 1974 abolishing AEC and creating a developmental agency, ERDA and an independent regulatory commission, NRC. The act gives NRC licensing and related regulatory authority over ERDA, now DOE, facilities "used primarily for the receipt and storage of high-level radioactive waste."

DEVELOPMENT OF "CONFIDENCE" RULEMAKING

Reference: III-I1—June 1976

The State of California passes three laws specifying the conditions under which nuclear reactors could be sited within the State. One law prohibits reactor siting until a finding has been made that "a demonstrated technology or means of permanent, terminal disposal of high-level nuclear waste exists and has been approved by the United States through its authorized agency."

Reference: III-I2—December 1976

NRC receives a petition from NRDC which requests that the Commission conduct a "rulemaking proceeding to determine whether radioactive waste can be generated in nuclear power reactors and subsequently disposed of without undue risk to the public health and safety and that the Commission refrain from acting to grant pending or future requests for operating licenses until such time as this definitive finding of safety can be and is made."

Reference: III-I3—June 1977

NRC denies the NRDC petition. The Commission concludes that it "would not continue to license reactors if it did not have reasonable confidence that the waste can and will in due course be disposed of safely. The accumulating evidence continues to support NRC's implicit finding of reasonable assurance that methods of safe permanent disposal of high-level waste can be available when they are needed. Given this, and the fact that at present safe storage methods are . . . available and highly likely to remain so until a safe disposal system can be demonstrated, the Commission sees in the waste disposal question no reason to cease licensing reactors."

Reference: III-I4—May 1979

The D.C. Circuit Court of Appeals rules in a case involving expansion of spent fuel storage capacity at the Prairie Island, Minn., reactor that NRC should reconsider its statement of confidence issued in response to the NRDC petition. Such reconsideration would be "in the interest of sound administration" given developments in the S-3 case and other recent events such as an IRG report.

Reference: III-I5—October 1979

NRC initiates a rulemaking proceeding on the storage and disposal of nuclear waste. The proceeding is intended to provide NRC an opportunity to reassess its degree of confidence that radioactive waste produced by licensed nuclear facilities will be safely disposed of offsite, to determine when any such disposal or offsite storage will be available, and if disposal or offsite storage will not be available until after the expiration of the licenses of certain nuclear facilities, to determine whether the waste generated by those facilities can be safely stored onsite until such disposal is available.

DEVELOPMENT OF WASTE MANAGEMENT GOALS

Reference: III-J1—June 1978

NRC publishes for comment a task force report on *Proposed Goals for Radioactive Waste Management.* The report and accompanying *Essays on Issues Relevant to the Regulation of Radioactive Waste Management* had been completed 18 months earlier but had been held by NRC.

DEVELOPMENT OF SPENT FUEL STORAGE REGULATIONS

Reference: III-K1—October 1978

NRC reveals a proposed new regulation that specifies procedures and requirements for issuance of licenses to store spent fuel in an independent spent fuel storage installation. The proposed regulation contains requirements for the siting, general design criteria, and certain operational aspects of such an activity.

DEVELOPMENT OF HIGH-LEVEL COMMERCIAL WASTE REGULATIONS

Reference: III-L1—November 1978

NRC publishes for comment a Proposed General Statement for Policy outlining procedures for licensing geologic high-level radioactive waste repositories to be constructed by DOE.

Reference: III-L2—December 1979

NRC withdraws its Proposed General Statement of Policy and substitutes proposed licensing procedures for a high-level repository. The procedures mandate a site characterization review, specify that several, three to five, sites in different geological environments must be characterized at depth, and indicate that approval must be obtained prior to repository operation and upon its decommissioning.

Reference: III-L3—May 1980

NRC publishes an advanced notice of proposed rulemaking setting forth its current views about the technical criteria which should govern the licensing of a repository. The proposed rule addresses these issues: the use of multiple barriers, the process of model validation, the treatment of geologic uncertainties, and the problem of human intrusion. One performance objective proposed is that waste packages be designed so that "there is reasonable assurance that radionuclides will be contained for at least the first 1,000 years after decommissioning and for as long thereafter as reasonably achievable given expected processes and events as well as various water flow conditions including full or partial saturation of the underground facility."

Reference: III-L4—February 1981

NRC adopts final procedural regulations for licensing a high-level waste repository.

Reference: III-L5—March 1981

NRC formally proposed the technical regulations for a high-level waste repository.

PART IV

Federal Waste Management Structure and Responsibilities

Reference: IV-A1—1955-70

The responsibility for radioactive waste management was highly fragmented. The organizations within AEC with major involvement included:

Division of Production.—Responsible for programs for high-level waste management and long-term storage of radioactive waste from AEC's chemical processing operations located at Hanford, Savannah River, and Idaho—after 1936. Most of the work and policy development is delegated to the contractors operating those facilities.

Division of Operational Safety.—Responsible for developing radiation protection standards and for appraising and evaluating the performance of AEC, field offices in the protection of health, safety, and property.

Division of Reactor Development and Technology.—Responsible for planning and technical direction of research and development on processes for the treatment and storage of high-level radioactive waste resulting or expected to result from chemical reprocessing operations in connection with the nuclear power industry. Much of its work in waste management is undertaken by Oak Ridge National Laboratory, the Pacific Northwest Laboratory, and other national laboratories.

Division of Materials Licensing.—Under the Director of Regulation: Responsible for licensing facilities for reprocessing irradiated source and special nuclear materials and therefore concerned with the adequacy of waste management activities at those facilities. Also responsible for low-level waste disposal activities.

It should be noted that most of these divisions underwent several metamorphoses during this 15-year period. Their names changed; their programs grew in size and were assigned to varying subunits.

Reference: IV-B1—May 1970

Division of Waste and Scrap Management formed as a staff division. It took over some responsibilities from the Division of Operational Safety, the Production Division, the Division of Operational Safety, and the Division of Reactor Development and Technology but had no independent budget. Thus, it had policy, planning, and appraisal functions but was not a strong technical division.

Reference: IV-C1—June 1971

Division of Waste Management and Transportation created. It has its own budget and took over policymaking for management of waste from the commercial nuclear industry.

Reference: IV-D1—January 1975

AEC is abolished; ERDA and NRC are established in its place. The Division of Production, Operational Safety, and Waste Management and Transportation become part of ERDA. A waste management branch is established as part of the Office of Nuclear Material Safety and Safeguards at NRC.

Reference: IV-E1—June 1975

ERDA reorganizes its waste management program. The Division of Waste Management and Transportation is abolished and its programs transferred to two new divisions. Commercial and military waste programs are brought under the umbrella of the Division of Nuclear Fuel Cycle and Production. All program planning, near-term research, development, demonstration, and operation of facilities for treatment, storage, and disposal of commercial radioactive waste, and the establishment and operation of Federal repositories for the ultimate disposal of all radioactive waste become the responsibility of an Assistant Director for Reactor Products and Inventory Management. A Division of Environmental Control Technology takes over responsibility for very, long-term waste management research. The Division of Nuclear Fuel Cycle and Production later becomes known as the Division of Waste Management, Production, and Reprocessing.

Reference: IV-F1—January 1976

ERDA contracts with Oak Ridge National Laboratory to create an Office of Waste Isolation (OWI). OWI was responsible for managing the research and development aspects of the National Waste Terminal Storage Program.

Reference: IV-G1—March 1977

NRC expands its waste management organization. An Assistant Director for Waste Management position is created. The Assistant Director is in charge of two branches, one dealing with high-level and transuranic waste, the other dealing with low-level waste.

Reference: IV-H1—October 1977

DOE comes into existence. Policymaking takes place largely in the Office of the Director of Energy Research. Operations are carried out in the Office of Nuclear Waste Management. That Office contains three major divisions: Waste Isolation, Waste Products, and Transportation and Fuel Storage. The Office initially reports to the Director of Nuclear Programs. Later on, ONWM reports to the Assistant Secretary for Energy Technology. The change is designed to give the Office of Nuclear Waste Management more public visibility and significance.

Reference: IV-I1—October 1978

The contract with OWI expires and is not renewed at the request of Union Carbide, the operator of Oak Ridge National Laboratory. Battelle Memorial Institute is selected to take over the management of the National Terminal Waste Storage Program. Battelle creates the Office of Nuclear Waste Isolation to carry out this task.

Reference: IV-J1—January 1979

NRC further expands its waste management operations, creating a Division of Nuclear Waste Management.

Table A-2.—Time Line—Parts I-IV, 1944-81

Year	Part I	Part II	Part III	Part IV
1944	A1	—	—	—
1952	A2	—	—	—
1953	C1,C2	—	—	—
1954	B-1	—	—	—
1955	—	—	—	A1
1956	A-3	—	—	A1
1957	B-2	A1	—	A1
1958	A-4	C1	—	A1
1959	—	A2	—	A1
1960	B-3	—	—	A1
1961	—	—	—	A1
1962	—	A3	—	A1
1963	C2,D1	—	A1	A1
1964	—	—	—	A1
1965	A5	B1	—	A1
1966	D2	B3,C2	A2	A1
1967	A6	B2	B1	A1
1968	—	—	—	A1
1969	—	—	—	A1
1970	C3	B4,B5,B6,C3	C1,D1	A1,B1
1971	A7	A4,B7	—	C1
1972	D3,E1	A5,B8,C4,C5,D1	A3,E1	—
1973	A8,A9	—	—	—
1974	E2	A6,B9	E2,F1,G1,H1	—
1975	E3	A7,D2	G2	D1,E1
1976	C4,D4	A8,A9,D3	A4,E3,E4,I1,I2	F2
1977	F1,F2	A12	F2,I3	G1,H1
1978	—	A13,A14,A15,A16,B10,B11	E5,J1,K1,L1	I-1
1979	D5	A10	E6,G3,I4,I5	J1
1980	—	A11,A17,B12,B13,B14	L3	—
1981	F3	—	L4,L5	—

Appendix B

Waste Management System Issues Resolved in the Nuclear Waste Policy Act of 1982

Introduction

This appendix discusses the major waste management system issues that were debated in the 97th Congress and addressed in the Nuclear Waste Policy Act of 1982 (NWPA). Questions concerning development and operation of the waste management system authorized by NWPA are discussed in chapter 6.

When the 97th Congress began its debate of radioactive waste management legislation, no firm agreement had been reached on whether final isolation of radioactive waste would be accomplished through storage or disposal, where and when to develop final isolation facilities, or how to store the waste before final isolation.

Several factors complicated congressional decisionmaking about storage and disposal. First, the unavailability of disposal and reprocessing had created the need for greater and longer term spent fuel storage capacity than originally envisioned. Because of the delays in developing both reprocessing and disposal facilities, it appeared likely that most of the spent fuel generated in this century would still be in interim storage facilities at the end of the century—even if direct disposal of spent fuel were to begin on the earliest possible schedule estimated by the Department of Energy (DOE). Furthermore, the possibility that reprocessing might become economical sometime in the future raised questions about whether to plan for storage of spent fuel as a potential resource or disposal of spent fuel as a waste—or both.

Thus, for the next several decades, waste management would consist almost entirely of spent fuel storage, and any reprocessing that occurred would simply convert some of the stored spent fuel into stored wastes of various types (solidified high-level waste, transuranic waste) and, perhaps, unrecycled plutonium. Moreover, it appeared that even after the capacity for disposal were available, storage might continue to be a major part of waste management—either because disposal would be deferred after disposal facilities were available (e.g., to maintain access to spent fuel for possible reprocessing or to reduce the heat output of the waste before disposal) or simply because it would take a long time to eliminate the backlogs of spent fuel built up in storage by the time disposal began.

The following policy issues address:

1. the overall Federal strategy for developing a final isolation system for high-level radioactive waste;
2. the schedule for developing final isolation facilities;
3. whether the final isolation system should accept only high-level waste, spent fuel, or both; and
4. the Government's role in interim spent fuel storage until final repositories are available.

These issue discussions were written prior to the passage of NWPA, and were the basis for OTA's summary report published in April 1982 during the debate on the Act and for extensive OTA testimony and staff analyses provided to Congress during that debate. These issue discussions are presented in the present tense, as they were originally written, to give a clear picture of how the issues and possible options were viewed during the debate that occurred before final passage of the act. Each issue discussion is followed by a brief description of the resolution contained in the NWPA.

ISSUE 1:

What approach should be used for developing facilities for final isolation of high-level radioactive waste?

Prior to passage of the NWPA, existing laws and regulations gave DOE the authority and responsibility to develop a final isolation system for high-level radioactive waste. While there was broad agreement that the Federal Government should proceed to develop such a system, there was less agreement about the kind of isolation needed and the pace of the program for developing isolation facilities.

In particular, there was disagreement about whether final isolation should be accomplished through disposal, which does not depend on continued human maintenance and monitoring to provide isolation, or through storage, which does. Existing law did not specify which approach to final isolation would satisfy the obligations of the Federal Government and did not even clearly distinguish between the terms "storage" and "disposal."[1] No generally accepted approach for the final isolation program had yet emerged from the congressional debates or from the administration's review of waste management policy. The history of the waste management program made it clear that resolution of this issue in law would be needed to avoid continued shifts of direction in the waste management program.

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[1] See app. note.

OPTION:
1. *Develop a disposal system of mined geologic repositories.*
2. *Defer developing geologic disposal and do research on many disposal technologies before selecting one for full-scale development.*
3. *Develop a permanent storage system.*

The Debate

The three options differ in the degree of commitment to the development of a disposal system. Option 1 immediately commits to developing the disposal technology that is best understood—the mined geologic repository. Option 2 assumes that a disposal system must be developed sooner or later, but defers that action for an extended period—say, 50 years or more. Option 3, in contrast to the others, favors developing a permanent storage system instead of a disposal system, based on the assumption that such storage would be an acceptable method for final isolation.

Since there is no alternative to continued storage of spent fuel (or reprocessed waste) until a disposal system is available, the options also entail different emphases on the development of Federal storage facilities. Option 1 is compatible with the provision of little, if any, Federal spent fuel storage capacity (see issue 4), since the option emphasizes prompt development of geologic repositories to which utilities could deliver their spent fuel. With option 2, the immediate focus of the waste management program would probably be development of centralized Federal facilities for extended storage of spent fuel and high-level waste; meanwhile, research and development (R&D) activities could be conducted on a number of disposal technologies until a decision were made to select one and develop it full-scale.

In option 3, like option 2, the immediate focus would be on development of appropriate storage technology, location of suitable sites, and construction of facilities. In fact, since a permanent storage program may involve use of facilities designed to be replaced periodically, perhaps every 50 to 100 years, there may be little if any difference between the storage facilities developed under options 2 and 3. The following discussion briefly summarizes the principal arguments cited in favor of each option and compares the options in terms of a range of criteria.

OPTION 1:

Develop a geologic disposal system.

Some supporters of this option feel that an *acceptable* disposal technology, not necessarily the *best* possible one, is needed to complete the nuclear fuel cycle and that there is enough agreement about the potential of the mined geologic repository to justify its development as the first-generation nuclear waste disposal system. A commitment to developing a disposal system of mined geologic repositories—the most well-defined and extensively studied disposal concept—is justified by the fact that geologic disposal has survived many intensive reviews without identification of any insurmountable scientific or technical barriers to its safe implementation. Moreover, development of geologic disposal provides continuity with Federal waste management policy of the last several decades and is consistent with the Environmental Protection Agency's (EPA's) proposed general regulatory criteria, which preclude reliance on institutional control of a repository for longer than several hundred years.

Perhaps the principal argument in its favor is that it would avoid deferring an ultimate solution of the waste problem to future generations.[2] Because disposal, unlike storage, does not require perpetual human control to assure continued safe isolation, it avoids burdening future generations with a problem they did not create. Moreover, a disposal system provides better assurance that long-term safety will not be compromised by the loss or abandonment of adequate institutional control of the repositories before the emplaced waste has decayed to innocuous levels. Such concerns prompt some people to view development of a disposal system as a necessary step for removing the waste problem as a hindrance to future use of nuclear power.

OPTION 2:

Defer development of geologic disposal and do research on many disposal technologies before selecting one for full-scale development.

Those who agree that disposal will ultimately be required for final isolation of high-level waste disagree about how quickly a commercial-scale disposal system should be developed. This disagreement results from concerns about existing uncertainties associated with various disposal technologies and from not knowing when and if spent fuel will ever be reprocessed. Because the future role of reprocessing is unclear, it is also uncertain when there would be any solidified high-level waste for disposal and when or if it would be economical to dispose of spent fuel directly as waste. This consideration leads some to conclude that there is ample time to explore a number of disposal alternatives before selecting one for development.

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[2] Interagency Review Group on Nuclear Waste Management (IRG), *Report to the President*, T10-29442, March 1979, p. 37; see also U.S. Atomic Energy Commission, *Preliminary Draft Environmental Statement: Retrievable Surface Storage Facility—Commercial High-Level Radioactive Wastes* (Richland, Wash.: Nov. 8, 1974).

Completion of R&D on a number of disposal technologies would allow disposal techniques to be selected when required. Supporters of this approach argue that since there appear to be no compelling health and safety reasons for rapid disposal of high-level radioactive waste, and since safe and relatively inexpensive extended storage facilities can be developed, there is simply no urgency to choose a specific disposal technology immediately. In addition, extended storage prior to disposal would simplify the task of disposal by allowing the waste to cool longer and would allow easy retrieval of spent fuel in case reprocessing is begun in that period. Thus, an extended period of storage would avoid any irreversible actions while uncertainties about disposal technologies and the economic value of spent fuel are resolved.

The concept of extended storage was embodied in the Retrievable Surface Storage Facility (RSSF) that was proposed by the Atomic Energy Commission in 1974 but was subsequently dropped in favor of an aggressive pursuit of the development of mined repositories. Interest in development of facilities for extended, and perhaps permanent, storage was renewed in 1979 by a proposal to use existing tunnels at the Nevada Test Site for this purpose[3] and was subsequently embodied in a bill (S. 2189) approved by the Senate in 1980 that would have provided for the construction of Monitored Retrievable Storage (MRS) facilities.

OPTION 3:

Develop a permanent storage system.

Several principal arguments are made in favor of permanent storage over disposal for final isolation. First, permanent storage avoids the uncertainties about the long-term performance of geologic barriers that have been the center of the debate about geologic disposal. Second, since suitable storage facilities could probably be available earlier and at less cost than disposal facilities, they could provide an earlier demonstration of long-term isolation than would be possible with geologic repositories.

Third, since isolation in a storage facility does not depend on the properties of the facility site, suitable storage sites closer to the sources of waste generation could be found more easily and quickly than sites for geologic disposal facilities. Finally, storage provides ready retrieval of spent fuel for later reprocessing or for final isolation using a better technology, if one is developed later. It thus preserves options for future generations.

Comparison of Options

PUBLIC HEALTH AND SAFETY

The principal objective of waste management is isolation of radioactive waste from the biosphere so that it poses no significant threat to human health and life. Several safety-related factors affect the choice between the three options under consideration.

All options could involve extended storage before disposal because they either defer availability of a disposal system for many decades (options 2 and 3) or might continue storage even after disposal facilities are available (option 1). Thus, the decision addressed in this issue is not when to dispose of waste irretrievably, but when to make available the capacity to do so. However, in order to highlight the differences between the options, this discussion of safety questions assumes that under option 1, disposal would begin as soon as a geologic repository becomes available.

Both the Interagency Review Group (IRG) report and DOE's environmental impact statement on high-level radioactive waste explicitly considered the safety benefits of early disposal in mined geologic repositories (option 1) compared with those of extended storage (up to 40 years) to allow development and possible use of alternative disposal technologies (option 2). The reports concluded that there are no compelling reasons of public health and safety for rapid disposal of high-level radioactive waste, since safe interim storage for such periods could be accomplished.[4]

On the other hand, they also concluded that mined repositories offered the most immediate and sure choice for development of an adequately safe disposal system and that there were no clear safety advantages to waiting for development of a better system, so long as a technically conservative repository development process were used.[5] In addition, EPA's proposed general criteria for radioactive waste disposal implicitly rule out storage as a permanent solution by excluding reliance on long-term institutional control as a means of assuring isolation.[6] Finally, the IRG agreed that a disposal system should be developed:

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[3] Phillip Hammond, "Nuclear Wastes and Public Acceptance," *American Scientist*, vol. 67, No. 2, March-April 1979, pp. 146-150.

[4] IRG, *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste*, TID-28818, October 1978, p. 53; U.S. Department of Energy (DOE), *Final Environmental Impact Statement on Management of Commercially Generated Radioactive Waste (FEIS)* vol. 1, DOE/EIS-0046F, October 1980, p. 1.31.

[5] DOE, op. cit., pp. 7.39-7.41; IRG, *Report to the President*, ch. 2.

[6] U.S. Environmental Protection Agency, *Draft Environmental Impact Statement for 40 CFR 191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, December 1982, p. 123.

> The responsibility for establishing a waste management program shall not be deferred to future generations. Moreover, the system should not depend upon the long-term stability or operation of social or governmental institutions for the security of waste isolation after disposal.[7]

As noted in chapter 3, the possible ways that radioactive waste might escape from a geologic repository over periods of a million years or longer have been considered in great detail by many analysts. In developing release standards for geologic disposal, EPA evaluated a wide range of possible release mechanisms, including inadvertent human intrusion, and concluded that a geologic repository could produce health effects over a 10,000-year period that are small compared with the effects of background radiation. The expected health effects would also be within the range of effects that could be caused by exposure to the bodies of uranium ore needed to produce the amount of fuel that would be contained in the repository.

No analysis comparable in time horizon or range of accident conditions now exists of the safety of storage as a substitute for, rather than simply as a prelude to, disposal as a means of permanent waste isolation (option 3). Potential risks of storage over a 10,000-year period would have to be analyzed in order to allow a consistent comparison with geologic disposal in terms of the proposed EPA standards.

Perhaps the basic question in comparing the safety of permanent storage with geologic disposal is whether the uncertainties about the reliability of the barrier provided by continued institutional control and maintenance are greater or less over such a long time period than those related to the performance of the geologic barriers they are intended to replace. Some qualitative insight can be gained by comparing the risks from a permanent storage facility with those from a geologic repository under two possible scenarios for institutional control: 1) the technical capacity and the societal will to maintain such control continue for the required period of isolation, and 2) the capacity or the will is lost at some point during that period.

1. *Institutional Control Is Maintained.*—Permanent storage may provide greater assurance than could geologic disposal that radioactive waste will not escape into the biosphere as long as the storage facility is kept under adequate control by today's standards and as long as repairs and replacements are made, as needed, to ensure continued isolation. Moreover, waste leaked from a storage facility could be easier to detect and clean up than waste leaked from a geologic repository. It should be noted that published calculations of the long-term health effects of geologic disposal, such as those performed by EPA, generally assume that the releases from the repository are *undetected* and therefore that no efforts are made to mitigate them or to prohibit the use of contaminated water and food.

In either case, as long as society can and will continue to monitor a waste repository so that leaks can be detected, such leaks will not impose an *involuntary* health risk on future generations. They would have the choice of accepting the risks or bearing the financial and social costs of mitigating the effects of the leaks. While permanent storage instead of disposal could reduce the cost of cleanup and mitigation measures in the unlikely event of significant unanticipated releases from a repository, these potential savings would have to be balanced against the certain higher financial costs, as well as radiation exposures to workers involved in maintaining a storage facility and in providing replacement facilities, as needed, for millennia.

2. *Institutional Control Is Lost or Abandoned.*—If there is significant concern that adequate institutional control will be terminated prematurely, geologic disposal may appear to be the safest final isolation alternative. In that event, the risk from a permanent storage repository would probably be greater than from a geologic repository since the former would more likely be located at or near the Earth's surface and would be designed to provide long-term isolation only with continued human care. In contrast, a geologic disposal facility would be several thousand feet deep at a site carefully selected to minimize the likelihood of significant releases—on the assumption that institutional control would not be used to provide the desired degree of isolation.

Adequate institutional control could cease either because of loss of social ability to care for the waste (through war or social regression) or because of carelessness or neglect. It can be argued that if something serious enough to cause society to lose its ability to care for radioactive materials occurs, then the possibility of low-level leakage from a waste repository may be one of the less important problems that society faces. On the other hand, it can be argued that the acceptability of the risks imposed on future generations should be independent of any consideration of unrelated risks they may be facing.

It can also be argued that the Government can be expected to act responsibly as long as it has the technical capacity to do so and that, in any case, this generation cannot take responsibility for the decisions of future generations. On the other hand, stored nuclear waste might be mishandled in the future in the same way that some toxic chemicals have been mishandled in the past, posing a risk not only to the generation responsible, but also to the generations that follow it. In some cases, the immediate risk to the generation responsible or to its immediate descendants might be relatively low, since the waste canisters should provide a barrier to release for perhaps a century or longer (depending on the design).

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[7] IRG, *Report to the President*, p. 16.

The risk would be imposed on later generations when the facility and the waste packages have deteriorated substantially and the waste has had time to leach into water and be transported to drinking water or food—a process that could take centuries. Thus, reliance on continued institutional control as the principal means of protecting future generations requires confidence that each successive generation will have the same ability to manage waste and will maintain our degree of concern and responsibility for the safety of the generations that come after them. In contrast, permanent disposal in facilities that do not require continued care and maintenance is not vulnerable to the possibility that today's standards for protection of health and safety of future generations will not be maintained.

Permanent storage involves one additional safety consideration if spent fuel rather than reprocessed waste were to be stored—the possibility of theft to recover the plutonium in the spent fuel for use in nuclear weapons. As long as the storage facilities are under control, this risk is low, particularly with spent fuel that is less than 100 years old and therefore too highly radioactive to handle easily. Older spent fuel could be a more attractive target for theft—a serious concern in case institutional control of the facility were lost. While spent fuel that had been disposed of in a geologic repository could also theoretically be recovered for use in nuclear weapons, this clearly would entail a much more difficult and time-consuming process than recovery from a surface storage facility.

STATUS OF TECHNOLOGY AND LICENSING[8]

Technical reviews have concluded that suitable sites for a geologic repository could be found, and a repository could be developed, licensed, and operating by the end of the century (perhaps earlier), provided adequate and stable resources were devoted to the task. The steps required in the National Environmental Policy Act (NEPA) for a DOE decision to develop a geologic disposal system have been completed, and the technical basis for the decision has been published in the required environmental impact statement.[9]

The remaining uncertainties about geologic disposal can only be reduced by proceeding to locate, characterize, and develop candidate repository sites, a process now being carried out by DOE. Moreover, the Nuclear Regulatory Commission (NRC) has issued final regulations for procedures to be used in licensing a geologic repository and for technical requirements for such a repository. EPA has developed tentative performance criteria for geologic repositories, and issued them for comment. It appears likely that the entire regulatory structure for licensing geologic repositories could be in place within several years.

Little technical doubt appears to remain that storage facilities suitable for extended periods can be designed and operated to meet current radiation protection standards as long as institutional control is maintained. One of the new dry storage technologies would probably be used for this purpose.[10]

NRC has issued regulations (10 CFR 72) for facilities designed for interim spent fuel storage for periods of up to 20 years, renewable at the discretion of NRC. Analysis by DOE suggests that a facility to meet these regulations could be designed, constructed, and licensed in about 10 years. However, it is not certain that these regulations would apply without modification to a facility explicitly designed for extended storage, as contemplated in option 2.

This regulatory uncertainty is even greater for a permanent storage facility (option 3). If the 10,000-year release criteria now under development by EPA for geologic repositories would also apply to a permanent storage facility, additional design requirements (e.g., a more complex and long-lasting waste package design) might be needed to protect against loss of institutional control during that period. It might also be necessary for NRC to develop a special set of technical regulations for permanent or extended storage facilities analagous to those proposed for geologic repositories.

COST

A detailed comparison of the costs of the three options must await both clarification of the regulatory requirements for storage and disposal facilities and development and analysis of alternative system designs that are comparable in total capacity and annual handling rates. Available studies indicate, however, that for several reasons it will be less expensive to develop storage facilities than disposal facilities.

First, the less stringent technical requirements for storage sites should reduce the initial costs of system development. Determining the suitability of potential sites for geologic repositories requires extensive and expensive tests at the proposed repository depth—estimated to cost more than $100 million per site. Such testing is not required for siting surface storage facilities. In addition, it may be necessary to incur these high costs at a number of sites in order to find one that survives the entire evaluation process.

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[8] See ch. 3 for a more extended discussion of the status of storage and disposal technology.

[9] DOE, *FEIS*.

[10] D. E. Rasmussen, *Comparison of Cask and Drywell Storage Concepts for a Monitored Retrievable Storage/Interim Storage System*, Battelle Memorial Institute, Pacific Northwest Laboratory, PNL-4450, December 1982.

Second, the construction costs would probably be lower for a storage facility located at or near the Earth's surface than for a geologic repository mined at a depth of several thousand feet. The initial capital costs of a geologic repository are likely to exceed $3 billion,[11] compared with initial capital costs of perhaps $500 million for a long-term surface dry storage facility using casks or drywells.[12] Even if mined tunnels (as proposed in one design) were used for storage, such a facility should involve less mining than a geologic repository for a given amount of waste because the continued ventilation in an open storage facility would allow more waste to be emplaced in a given area while maintaining temperatures at acceptable levels.

In addition, the acceptable temperatures might be higher in a storage facility than in a geologic repository. With a storage system there is less concern about the long-term effects of heat on the characteristics of the site, and any adverse effects on the facility or the waste canisters could be repaired. Higher acceptable temperatures could further reduce the comparative cost of a storage facility.

It is difficult to compare long-term costs because storage involves a perpetual stream of payment for maintenance, repair, and replacement of facilities, while geologic disposal involves, at most, the continued cost of monitoring once the facility has been filled and sealed. Disposal thus concentrates costs nearest the time the waste is generated, while storage spreads the costs out over many generations. Therefore, the costs of permanent storage over the entire period of monitoring and maintenance could exceed the costs of disposal, which can be fairly well defined and bounded because they are limited to a relatively short period of time.[13]

If storage were intended only for an extended period (say 50 to 100 years) prior to development of a disposal system (option 2), then the costs of storage would be an addition to, not a substitute for, the costs of the prospective disposal system. However, extended storage might reduce the direct costs of disposal somewhat because the cooling of the waste over that period could allow greater loading of waste in a geologic repository. (It should be noted that if the intention is to increase the long-term safety of the repository or the predictability of its long-term performance by cooling the waste before it is emplaced in the repository, thereby lowering repository temperature, it may not be possible to increase significantly the amount of waste emplaced without losing this advantage.)

Any discussion of long-term costs must take account of discounting, a procedure that gives more weight to early expenditures than to later ones in order to reflect the time value of money. Discounting is used to calculate the present value of a future expenditure by determining what amount of money would have to be invested in the present at the assumed discount rate (or interest rate) to yield an amount equal to the future expenditure by the time that expenditure is incurred. For example, since $1 invested at 10 percent would yield $1.10 a year from now, the present value of an expenditure of $1.10 a year from now, using a 10 percent discount rate, is $1. At a 3 percent annual discount rate, $1 spent 100 years from now would have a discounted present value of 5 cents.

The discounted total cost of permanent storage could be less than the total cost of disposal, since the discounted cost would be determined primarily by the costs of construction and maintenance of the initial storage facilities, which should be less than the same costs for disposal facilities. The cost of replacing storage facilities, which might be necessary after the first 100 years or so, would have little effect on the discounted total cost. For the same reason, the discounted cost of interim storage followed by disposal (option 2) could be less than the cost of early disposal, simply because deferral of disposal costs reduces the contribution of disposal to the present value of total waste management costs.[14]

There is no consensus about whether it is appropriate to use discounting when considering costs and benefits that affect many generations, because discounting strongly favors present benefits over future costs.[15] To avoid shifting the costs of maintaining a storage system to future generations, the present generation would have to collect the discounted present value of those costs now and invest them at a rate of return sufficient to earn the discount rate assumed in calculating the present value, over and above the rate needed to keep pace with inflation. No analysis has been done of possible financial mechanisms that could be used to assure that the costs of perpetual care of radioactive waste would be borne primarily by the generation that created the waste.

FLEXIBILITY

All three options for final isolation offer some flexibility for taking advantage of more desirable alternatives in the future or for maintaining access to radioactive waste; even option 1 allows the choice to continue storage even after disposal facilities are available. Thus, a decision to develop a disposal system is *not* the same as a decision to dispose of anything irretrievably on any particular schedule in the future; indeed, it is difficult to imagine how a decision could be made that would effectively force future decisionmakers to dispose of waste irretrievably on any fixed schedule if it appeared unsafe or unwise at that future time to do so.

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[11] DOE, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive Waste*, DOE/S-0020, June 1983, table 3.4, p. 13.

[12] Rasmussen, op. cit., tables A.27 and A.28, pp. A.28-A.29.

[13] DOE, *The Monitored Retrievable Storage Concept*, DOE/NE-0019, December 1981, p. 2-35.

[14] Ibid.

[15] See, for example, Robert E. Goodin, "Uncertainty as an Excuse for Cheating our Children: The Case of Nuclear Wastes," *Policy Sciences*, 10, 1978, pp. 25-43.

The capacity for surface storage could be provided at mined repository sites for a relatively small incremental cost, since a mined repository would have a waste receiving and packaging facility that could package waste for emplacement either in a surface storage system or in the repository.[16] In fact, a mined repository may require surface storage capacity to handle surges in deliveries to the repository, to continue receiving waste if loading of the repository were temporarily halted, or to allow the repository to be unloaded expeditiously if that became necessary. Thus, the higher cost of developing a system of mined repositories would provide the technical capacity and the sites for both storage and disposal.

From this perspective, the difference between option 1, on the one hand, and options 2 and 3, on the other, is not *whether* Federal facilities for long-term storage would ever be built, but *where* they would be built—at sites that are suitable for untended disposal or at sites that are only suitable for monitored and maintained storage.

Option 3, and the initial phase of option 2, would provide the option only of storage. A later decision that a disposal system was needed would entail the expenditure of additional billions of dollars by future generations to find and develop suitable disposal sites and to construct additional handling and packaging facilities at those sites. Thus, a decision to store waste for an extended period would be more reversible if the storage were done at a mined repository site than at a site suitable only for storage, since the capacity for disposal would be immediately available onsite (if the repository were already built and money were available) and the costs of moving the waste from storage into the disposal facility would be minimal. In addition, the extended storage period at the repository site could be used to continue analysis of the suitability of the site for permanent geologic disposal, thus providing a larger body of data on which to base a decision about irretrievable disposal.

A decision to develop long-term, easily expandable Federal storage facilities instead of or before disposal facilities would probably create strong budgetary pressures to continue to expand the storage capacity and to defer raising and spending the additional funds needed to develop a disposal system. Availability of Federal storage facilities would remove a major source of pressure for developing a disposal system by providing an effective solution to the waste problem for utilities. In addition, expansion of storage facilities using modular dry storage technologies would be easier and cheaper than developing a disposal system. These advantages lead some to conclude that the decision in option 2 to defer commitment to development of disposal facilities could be, by default, a decision to store waste permanently.

If approval of permanent storage for final isolation (option 3) satisfied State laws linking continued licensing of reactors to the existence of an approved final isolation method, it might imply that no other system need be developed as a precondition for continued generation of waste. Moreover, if permanent storage were approved, it might be difficult to justify charging nuclear utilities and their ratepayers any more than is required to cover the costs of a Federal storage system. In that event, a waste management trust fund financed by direct fees on the users of nuclear electricity would be adequate only to assure continued maintenance and replacement of storage facilities as needed. The longer the period of storage, the more difficult it could be to raise the additional billions of dollars needed for disposal from future utility ratepayers or Federal taxpayers who did not contribute to the generation of the waste or to decisions about how waste would be managed.

Thus, development of a stand-alone storage system, required for options 2 and 3, may be less reversible than development of a geologic disposal system, which provides a relatively easy choice between continued storage or disposal. *In fact, there may be little practical difference in reversibility between options 2 and 3, even though the storage facilities required in option 2 are only intended to be used as an interim step prior to final disposal.*

PUBLIC ACCEPTABILITY

There appears to be little disagreement that developing a disposal system that meets appropriate safety standards would satisfy public concerns about the obligation to protect the health and safety of this and future generations. However, there is disagreement about whether it is *necessary* to develop a disposal system now, or whether development of a Federal storage system would be sufficient to allow the continued generation of waste. The history of strong and successful opposition to Federal efforts to develop storage facilities (first the retrievable surface storage facilities, later an away-from-reactor facility) demonstrates that some feel strongly that storage is not an acceptable alternative to disposal. Moreover, they fear that the availability of Federal storage facilities might lead to continued deferral of development of disposal technology.[17]

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[16] Rasmussen, op. cit., pp. 1.5-1.6.

Supporters of options 2 or 3 argue that storage for the foreseeable future might be more acceptable because it avoids the technical uncertainties in geologic disposal that result from reliance on predictions of very long-term performance of natural and manmade barriers. They are concerned that an exclusive focus on development of a geologic disposal system would make the demonstration of a satisfactory solution of the waste problem dependent on resolution of many complex technical debates about the performance of a geologic repository, a process that may take decades. They contend that an adequately safe storage system could be demonstrated more quickly and with greater confidence.

On the other hand, a shift in focus from disposal back to storage could create the impression that the Federal Government has serious doubts that technical uncertainties can be dealt with at all—an impression that could heighten, rather than reduce, public concerns about the waste problem.

Some argue that storage simply changes the nature of the uncertainties about safety from technical (associated with performance of geologic and manmade barriers) to social (associated with the dependability of continued institutional control). No hard evidence suggests that the public would be significantly less concerned about social uncertainties than about technical ones. From this perspective, demonstrating that waste can be safely stored as long as institutional control is maintained would simply not address the unavoidable long-term institutional uncertainties of final waste isolation.

The history of resistance to any deferral of the development of a disposal system suggests that if the Federal Government decided to construct a storage system (as either an interim or a permanent measure), concerns about the lack of progress on disposal could in the future become a major encumbrance on the use of nuclear power; for example, if there were efforts to expand the nuclear power system substantially before a disposal system were developed.

EASE OF SITING FACILITIES

Storage facilities may be technically easier to site than geologic repositories. Since the storage site would not be the major barrier to release of the contents of the facility, the technical requirements of the site would be less stringent, and the long-term performance of the site would not have to be demonstrated in the licensing process. (This advantage might be offset considerably in the case of permanent storage [option 3] if assurance of continued institutional control for a period of millennia must be demonstrated in the licensing process.)

It should be noted that various storage technologies may differ significantly in ease of siting. A preliminary screening by DOE indicates that about 20 percent of the area of the United States would be favorable for surface storage facilities (e.g., surface drywells), while only about 2 percent of the United States would be favorable for tunnel facilities (e.g., the tunnel rack system).[18]

The less demanding siting requirements for surface or near-surface storage compared to geologic disposal may not translate directly into substantially greater ease and speed in siting facilities. An underlying not-in-my-backyard sentiment may be a major obstacle to siting, regardless of the type of facility being sited.[19] Although the greater number of potential storage sites should make it easier to find some States willing to accept a storage facility, site selection on that basis may limit the flexibility to locate facilities near the site of waste generation—one of the potential advantages of storage facilities compared with geologic repositories.

In practice, the relative flexibility of siting for storage facilities may increase their vulnerability to not-in-my-backyard sentiments precisely because the technical reasons for choosing any particular site would be much less strong than would be the case with a geologic repository. State and local resistance to a waste facility may be stronger if there is no compelling safety-related reason why it could not be located somewhere else just as easily. In addition, if a storage facility were proposed as a way to deal with delays in a disposal program resulting from political resistance to siting a geologic repository, it might not be unreasonable to expect the same sort of resistance to siting the storage facility.

INSTITUTIONAL IMPLICATIONS

It may be more difficult for the Federal Government to adopt and implement a commitment to the more expensive and complicated goal of developing a disposal system than to the less expensive and more incremental option of constructing storage facilities. The normal Federal policymaking and budgeting process tends to favor incremental actions for the most pressing problems, to defer decisions about issues that seem to require no immediate action to avoid serious consequences, and to avoid irreversible actions wherever possible—particularly when there is substantial uncertainty about the outcome of those actions.

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[17] DOE, *The Monitored Retrievable Storage Concept*, p. 2-37.

[18] Ibid., p. 3-17.

[19] A DOE study concluded that the mitigating measures needed to deal with State and local concerns would be very similar, if not identical, for either geologic repositories or long-term storage facilities. DOE, *The Monitored Retrievable Storage Concept*, p. 2-38.

For several reasons, this Federal decisionmaking process appears to be more compatible with the implementation of options 2 and 3 than with option 1. For instance, development of a Federal storage system would deal with what some see as the most pressing waste management problem—the utilities' need for some way to end their open-ended liability for growing inventories of spent fuel—while allowing the problems of siting geologic disposal facilities to be deferred. In addition, the annual Federal budget process may tend to favor storage over disposal, since it will be less expensive in the short run to construct a new storage facility or expand an existing one than to build a disposal facility.

The near-term cost advantage of storage would be increased by use of the dry storage technologies, now under development, that allow easy incremental expansion of storage capacity. While the continuing costs of maintaining storage facilities may make the total budget outlays for storage much greater than for disposal in the long run,[20] the near-term cost advantages could tend to dominate decisions.

Substantial changes in the institutional approach to waste management may be needed to give high credibility to a commitment to option 1 (see ch. 7), whereas no such changes would be necessary for options 2 or 3. The very flexibility and high degree of annual oversight and control normal in Federal programs opens the possibility that an option 1 policy would be changed in the future and storage facilities built as a way to buy time if problems arose in the disposal program or if the Federal budget were particularly tight when large appropriations for construction of a full-scale geologic repository were required.

The Resolution

In adopting the NWPA, Congress in effect chose option 1 by making an explicit commitment to development of mined geologic repositories, thus embodying in law the policy that had earlier been adopted by DOE. With regard to long-term storage of spent fuel or high-level waste, the Act recognizes that such storage is a potentially useful waste management option and requires DOE to submit an analysis of the need for MRS facilities and site-specific designs for the first such facility. However, the Act requires that disposal in geologic repositories should proceed regardless of whether an MRS facility is built. Development of a plan for long-term storage facilities would thus provide a backup option in case serious problems arise in the geologic repository program.

The remaining issues in this chapter discuss primarily those decisions that logically followed the selection of option 1 of issue 1. The question of the role of MRS facilities in the waste management program is considered at greater length in the discussion of the radioactive waste Mission Plan in chapter 6.

ISSUE 2:

What kind of schedule should be adopted for developing mined repositories?

One principal obstacle to development of a widely accepted waste disposal policy has been disagreement about the appropriate pace for developing geologic repositories. People who believe that the current base of knowledge will permit an acceptably safe system to be developed and implemented fairly quickly recommend rapid action to allay public concerns about waste disposal. Others believe that pressures for hasty action could lead to premature commitment to a repository site that is inadequate or, at the very least, to actions that would jeopardize the credibility of the Federal waste disposal program.

OPTION: 1. Accelerated schedule.
2. Conservative schedule.

The Debate

OPTION 1:

Accelerated schedule.

An accelerated schedule for developing a repository would involve evaluating the minimum number of possible sites (three) and geologic media (two)—required by NRC for selecting the candidate site for the first geologic disposal repository—so that submission of a license application for a repository would not be delayed while a broader range of alternatives was examined. Proponents of the accelerated schedule believe that a geologic disposal repository can be developed rapidly with little risk of failure and that any further delay would be interpreted by the general public as a lack of Federal commitment to complete the task and, perhaps, even as evidence that the job cannot be done at all. If successful, this approach could lead to a licensed repository in the late 1990's.

An accelerated schedule carries several potential risks. First, such a schedule could raise fears that safety might be compromised, in turn leading to continued efforts to delay or change the schedule yet again, as well as to criticisms of the program that could increase the doubts of the general public. Second, accelerating the schedule of development of a technology and licensing process for which there is no previous experience increases the risk of real or perceived failures to find or license sites.

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[20] Ibid., table 2-5, p. 2-25.

Such failures could reduce public confidence in the Federal waste management program.

A basic problem in establishing a schedule for development of a geologic repository is the first-of-a-kind nature of the process in terms of both the technical and institutional steps involved. Concerning this point, an official of the U.S. Geological Survey (USGS) stated:

> The types of information needed for site characterization and performance evaluation for licensing are fairly well understood by the interested agencies; however, the time required to perform the tests to obtain this information is uncertain . . . The site characterization phases will be a learn-as-we-go procedure in which we cannot accurately predict schedules. To complicate the scheduling, sociopolitical aspects of State and public participation can also impose unplanned delays in obtaining technical information.[21]

Adoption of an accelerated schedule in the face of uncertainties about siting poses three major risks. First, it may lead to premature selection of candidate sites on the basis of inadequate data, which could increase the chances that the first site recommended to NRC would not be approved. Considering the great political importance attached to the first repository, the negative effects on public confidence of rejection of the first site could be severe, especially if the selection were accompanied by considerable optimism about the ease of developing a repository. Second, slippages in the schedule, more likely to occur in an accelerated schedule, could weaken the credibility of the entire schedule, particularly if they occurred in the early stages of the process.

Third, to the extent that the feasibility of an accelerated schedule is questioned by the technical community and the involved agencies, the responsibility for real or perceived failures resulting from the schedule will be shifted to some extent from the involved executive branch agencies to Congress. This shift could reduce the extent to which the agencies could be held accountable for progress. Agency accountability will be greater if the agencies themselves develop and certify the feasibility of the schedule they are to meet.

OPTION 2:

A conservative schedule.

Advocates of a more conservative schedule for repository development—one that allows for unforeseen delays and provides ample time to review more sites and media and to resolve the remaining technical uncertainties—argue that a conservative approach is needed to build public confidence that the job is being done safely and that no corners are being cut in haste. (This approach is typified by the IRG recommendation of a cautious repository development process involving review of four to five sites in two to three geologic media before selecting a site for development.)

A conservative schedule poses risks of its own. In the first place, it may be no more capable of gaining broad public support than an accelerated schedule. While a conservative schedule deals with the concerns of those who fear that haste could compromise safety, it may not be responsive to concerns of those who believe that a rapid demonstration by the Federal Government of both the will and the technical capacity to dispose of radioactive waste is needed. In fact, strong dissatisfaction with the schedule implied by the Carter administration policy, which envisioned a repository perhaps not available until 2007, was a major reason for congressional efforts to accelerate the schedule and for the decision by the Reagan administration to speed up the process by examining only three sites in two media, the minimum required by NRC, before selecting a site for development.

Such a distant target date could generate a relaxed attitude towards the program schedule by those responsible for implementing it and may increase the risk of planning being minimal, of milestones being missed with few apparent consequences, and of the goal continuing to recede into the future.

Moreover, the further away the target date for a repository, the more strongly the utilities could argue that the Federal Government has a responsibility to take some earlier action to relieve them of the storage problem created by the slow Federal approach to repository development. If this action involved construction of a new Federal storage facility, such a facility would probably use one of the easily expandable dry storage technologies, such as the surface drywell, thus further reducing pressures for development of a repository and creating a relatively easy and economical way to continue to defer the costs of the disposal system.

Selection of the pace for repository development requires balancing the concerns that too fast a pace would not be consistent with safety against the concerns that too leisurely a pace would not allay public fears about waste disposal in a timely manner and would not adequately address utilities' concerns about an open-ended liability for storing growing inventories of spent fuel.

Agreement about an appropriate schedule may be facilitated by shifting the focus of the argument from the *speed* of the schedule to its *certainty* and *commitment*. Analysis performed by OTA suggests that what is most important in securing and sustaining public confidence, and in providing utilities with a solution to their spent fuel storage problem, is not how quickly a repository can be made available, but whether it will be available according to a firm schedule, backed by a firm Federal commitment, and accepted widely (by utilities, environmentalists, and all other interested parties) as feasible and reasonable in view of the remaining technical and institutional uncertainties about siting.

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[21] Testimony of James F Devine, Assistant Director of Engineering Geology of the USGS, before the Committees on Energy and Natural Resources and on Environment and Public Works, of the U.S. Senate, Oct. 6, 1981.

A firm Federal *commitment* to accept waste at a repository on a fixed but relatively cautious date would represent a strengthening of Federal determination and could provide the most complete and credible solution to the waste disposal problem for both the public and the nuclear utilities. Such commitment to a date might greatly ease the utilities' job of providing interim storage until that date by removing one of the major sources of objection to expanded at-reactor storage: the concern that such storage would become de facto final isolation.

A major concern with this approach is that the credibility of any future Federal schedules may be very low because schedules for the availability of a geologic repository have slipped drastically from 1985, as estimated in 1976, to 2006—at the latest—according to 1982 DOE estimates.[22] The problem is compounded by the significant institutional and technical uncertainties affecting progress in waste disposal.

A credible commitment to a firm date would require both a realistic target date and a conservative technical program for meeting it. The target date must strike a balance between speed and certainty. On the one hand, locating sites as early as possible would limit the buildup of spent fuel in interim storage facilities. On the other hand, too optimistic a date runs the risk of failure, which could have significant political impacts and could create difficulties for utilities that have made storage plans based on that date. To the extent that utilities need a *firm* schedule for their own planning, the reliability of the schedule may be more important than the speed.

A conservative target date for operation of the first repository would allow ample time for a second candidate site to be identified and carried through the licensing process independently of the first—thus increasing the confidence that a firm commitment to the target date could be met even if the first site were rejected by NRC. Such a possibility must be considered because of the lack of technical consensus about the likelihood of a site that appears acceptable after characterization ultimately receiving an operating license. *If the first site proves to be acceptable to NRC, a repository could be available earlier than promised.*

Recent DOE analysis concludes that a site in a medium (granite) not now under consideration for the first repository could be licensed by early 1999.[23] This suggests that a full-scale repository could be in operation by 2008 even if none of the sites under consideration at the time NWPA was being debated proved acceptable, provided that a backup siting program is pursued.

An acceleration and expansion of ongoing DOE activities may be needed to give high confidence that a commitment to a firm schedule—even a conservative one—can be kept in spite of technical and institutional uncertainties. In particular, the technical program would require enough backups to each component of the disposal technology and to each site to ensure that at least one acceptable combination would be available by the target date, even though more or less predictable difficulties and failures occur.[24]

There is now no technical consensus about the likelihood that any particular site that appears suitable for licensing at the end of site characterization will, in fact, survive the entire licensing process. For this reason, commitment to a schedule for the activities involved in identifying a first candidate repository site and taking it through the licensing process is not equivalent to a commitment to a schedule for availability of a licensed repository site.

The relevant agencies could meet every deadline in a schedule for the first candidate site and still wind up at the end of the licensing process with a rejection from NRC and thus no operating repository. While another site could be submitted if the first were rejected, the repository availability date would slip significantly, a fact which the public might well perceive as a major failure in the waste management program.

The most straightforward way to reduce the risk of licensing rejection is to provide the time and resources necessary to carry more sites than necessary through the site characterization process and into the licensing process so that backups are immediately available if the first site considered cannot be licensed. This redundant approach might increase the initial costs of developing the repository system. However, it appears certain that more than one site will eventually be needed anyway, so the effect on total management costs in the long run may be less significant.

Commitment to a fixed schedule will thus be more expensive, if the probability of failures is minimized, than commitment to a more flexible target date because of the greater redundancy needed to assure success on schedule. A detailed analysis of the additional cost would require development of a more detailed program plan than has been available to date.

In any case, the additional cost should have no significant effect on the economic competitiveness of nuclear power. For example, a program that was 160 percent more expensive than DOE's proposed program would add only about 0.1 cent per kilowatt-hour to the cost of nuclear generated electricity.[25] Furthermore, any cost increase may be more than offset by the reduced risk of incurring the costs of failure if reactors are forced to shut down. From this perspective, the extra costs of a conservative approach can be seen simply as the premiums for insurance against the costs of failure.

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[22] DOE, *National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment—Public Draft*, DOE/NWTS-4, February 1982, p. 112.

[23] DOE, *Mission Plan for the Civilian Radioactive Waste Management Program*, DOE RW-0005 Draft, April 1984, vol. I, p. 3-A-44.

[24] Redundancy is a standard design procedure in the development of highly reliable systems, and is routinely used in the U.S. space program.

The Resolution

The NWPA made a Federal commitment to a firm schedule for repository development by requiring that the first geologic repository begin operation by January 1998, the nearer end of the range of dates that DOE had estimated for that event. DOE analysis suggests that this date can only be met if the first site submitted for licensing is approved (or if a backup site is submitted at the same time as the primary candidate so that it would be available with no delay if the first is rejected); and if initial operation of the repository is achieved before the repository's full-scale receiving and packaging facilities are completed.[26] A more extensive discussion of this question, and of the program implications of the commitment to a firm schedule, is found in chapter 6.

ISSUE 3:

What provision for the possibility of reprocessing should be made in the waste management system?

As discussed in chapters 3 and 4, there is strong disagreement about whether spent fuel should ever be disposed of directly without reprocessing. This has been reflected in debates about the appropriate design for the high-level radioactive waste disposal system.[27]

OPTION: 1. *Design the disposal system assuming that all spent fuel will be reprocessed.*
2. *Design the disposal system assuming that no spent fuel will be reprocessed.*
3. *Design the disposal system to accommodate both spent fuel and reprocessed waste.*

The Debate

OPTION 1:

Design the disposal system assuming that all spent fuel will be reprocessed.

This option has two implications for system design. First, no provision would have to be made for direct disposal of spent fuel. A spent fuel disposal package and the equipment and facilities for packaging and emplacing spent fuel in a repository would not be developed, and sites with geochemical conditions suited for spent fuel disposal would not be sought. Second, provisions would probably have to be made for extended and indefinite storage of spent fuel because of the uncertainty about when reprocessing would be economical. This is quite compatible with a decision to provide a disposal system on a fixed schedule (issue 1). Once disposal sites were licensed, construction of full-scale disposal facilities could be deferred, if desired, and extended storage facilities could be constructed at the sites instead.

This option allows continued access to the unused uranium and plutonium in spent fuel and greater flexibility in the choice of a disposal system. Geologic disposal of reprocessed waste, and not spent fuel, permits tailoring the waste form to the characteristics of a particular repository and would allow separation and separate disposal of the heat-producing, but relatively short-lived fission products from the cool, but very long-lived transuranic elements in the waste. This option might also allow use of disposal systems such as space disposal that are not practical with spent fuel.

On the other hand, it now appears possible, if not likely, that even if the demand for electricity increases sharply enough to warrant large-scale use of breeder reactors, only part of the spent fuel expected to be generated by light-water reactors might have to be reprocessed to provide enough plutonium to start up the breeders. If breeder reactors are not used, there may be little commercial incentive to recycle uranium and plutonium for use in light-water reactors. Even if some recycling occurs, there could be an economic incentive to dispose of spent fuel containing plutonium that had been recycled several times previously.

Furthermore, a requirement that only reprocessed waste be disposed of could increase the cost of waste disposal by requiring reprocessing of spent fuel in some cases in which the cost of reprocessing could not be offset by sale of the recovered uranium and plutonium. Since this situation would probably require expenditure of billions of dollars for construction and operation of federally owned reprocessing plants, and since existing and proposed regulations would allow direct disposal of spent fuel without reprocessing, it seems likely that the choice would be made to continue to store spent fuel while developing the capacity to dispose of it directly. Thus, a decision not to provide the capability to dispose of spent fuel may lead to additional disposal costs in the future, either for uneconomic reprocessing of some spent fuel or for additional storage of that spent fuel while the capacity to dispose of it is developed.

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[25] Congressional Budget Office, *Financing Radioactive Waste Disposal*, September 1982, summary table p. xv.

[26] DOE, *Draft Mission Plan*, fig. 3-A-5, p. 3-A-38.

[27] See discussion of reprocessing in ch. 3 for technical background and references.

OPTION 2:

Design the disposal system assuming that no spent fuel will be reprocessed.

Developing the disposal system for spent fuel alone would involve planning for the use of disposal capacity as soon as it is available. The policy of the Carter administration appeared in many respects to be similar to this option. Reprocessing was deferred, work on waste forms was limited to the military program, and most studies of disposal policy published by the administration showed spent fuel being directly disposed of as rapidly as repositories could be made operational; however, the policy's stated purpose was to develop a disposal system that did not preclude future decisions to reprocess.

Developing the capacity to dispose of spent fuel directly would enable an earlier large-scale demonstration of waste disposal than would occur if the disposal system were designed only for reprocessed waste. Significant quantities of spent fuel could be disposed of as soon as a repository was available. A demonstration of disposal at commercial scale—which could involve emplacement of perhaps a thousand tonnes of spent fuel or more over a period of years—could answer questions about ability to license and operate a full-scale disposal system more completely than could a small-scale unlicensed technical demonstration.[28] It would also permit observation of repository performance under a significant heat load for an extended period.

One cost of the demonstration would be loss of the potential resource value of the spent fuel used. However, since existing reactors and those with construction permits alone would generate over 100,000 tonnes of spent fuel during their lifetimes, disposal of even 10,000 tonnes would represent less than 10 percent of the total and would lead to only a small increase in total uranium requirements if recycling and an expansion of nuclear power ultimately occurred.[29] The benefit of an early, tangible demonstration of commercial-scale waste disposal could offset the lost resource potential.

There are several disadvantages to designing repositories for spent fuel only. First, since practically all military high-level waste is reprocessed waste, designing a commercial system to manage only spent fuel would limit the range of options for dealing with military wastes. Second, the burden of developing the capacity to dispose of reprocessed waste may shift to the future if it turns out to be more economic to reprocess spent fuel than to dispose of it directly. Modifying the initial spent fuel disposal system design later to handle reprocessed waste could increase disposal costs.

OPTION 3:

Design the disposal system to accommodate both spent fuel and reprocessed waste.

The major advantage of this option is that it gives future decisionmakers the greatest range of choices and leaves open the option to reprocess spent fuel. This neutrality about reprocessing may be seen as a disadvantage by those who favor or oppose reprocessing for reasons not related to waste management. As discussed above, it is not clear that either option 1 or 2 can do more than inconvenience future decisionmakers, who can always use extended storage if reprocessing or direct disposal of spent fuel do not appear advisable.

As noted in chapter 3, recent major studies of the subject have concluded that mined repositories could be designed for both spent fuel and reprocessed waste without compromising safety. Of course, a system designed to handle both forms may be somewhat more expensive over the short term than a system optimized for one or the other, although no data are available to support an estimate of the additional cost. However, such a system may be less expensive in the long run since it avoids the possible costs of extended storage and system redesign necessary for conversion from a single-waste form system to a multiwaste-form system.

The Resolution

The NWPA provides that geologic repositories shall be capable of receiving either spent fuel or reprocessed high-level waste.

ISSUE 4:

What responsibility should the Federal Government assume for interim spent fuel storage before a permanent repository is available?

The delays in availability of both reprocessing and a Federal waste repository have presented utilities with two related problems. First, the existing spent fuel storage basins at reactors are filling up. Even if the capacity of existing basins is expanded by reracking to the maximum extent possible, and if utilities are allowed to transship fuel from reactors whose basins are filled to unfilled basins at other reactors, some face the risk of forced reactor shutdowns by the 1990's unless additional storage space is made available on a timely basis.[30]

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[28] Along these lines, one nuclear industry group recommended that some spent fuel should be placed in terminal waste disposal repositories for near-term demonstration purposes, although they did not recommend that spent fuel be routinely disposed of in repositories. "Spent Fuel and Nuclear Waste," a statement by the Atomic Industrial Forum's Study Group on Waste Management, Oct. 18, 1978.

[29] One study has concluded that a policy of disposing of spent fuel when it is 20 years old would not significantly limit the ability to develop breeder reactors. Brian G. Chow and Gregory S. Jones, *Nonproliferation and Spent Fuel Disposal Policy*, a report prepared for the Council on Environmental Quality (Marina Del Rey, Calif.: Pan Heuristics, October 1980).

[30] DOE, *Spent Fuel Storage Requirements*, DOE/RL-83-1, January 1983, table 4, p. 17.

Many utilities have expressed concern about whether they would be able to provide the needed additional storage capacity quickly enough to prevent reactor shutdowns.

Second, even if utilities were certain that they could provide additional storage when needed, the uncertainty about when spent fuel could be shipped to a reprocessing plant or a Federal waste repository leaves the utilities with an open-ended liability for growing inventories of spent fuel and no clear basis for planning their long-term storage needs. There is an important linkage between this long-term problem and the near-term problem of providing additional storage quickly enough to prevent reactor shutdowns. As noted in chapter 4, there has been growing opposition to efforts to provide additional spent fuel storage capacity because of fear that availability of interim storage would reduce pressures for developing long-term solutions, thus turning interim storage facilities into de facto permanent waste repositories.

The effectiveness of a storage policy in preventing reactor shutdowns may be the greatest determinant of its potential economic impact. As noted in chapter 3, the cost of replacement power for a 1-GWe reactor for 1 year could exceed the total discounted cost of permanent storage in a new water basin for all the spent fuel the reactor would generate during its operating lifetime. The ability to ensure timely availability of additional interim storage capacity is therefore a primary criterion for evaluating interim storage options. However, because the uncertainties about the long-term fate of spent fuel may constitute a serious obstacle to gaining the necessary approvals for interim storage facilities, it may be difficult to resolve the near-term storage problem in a timely manner without at the same time addressing the long-term question.

At present, it appears unlikely that the development of large-scale commercial reprocessing could provide a very timely or predictable way to ease the spent fuel storage problem at reactors. The private sector appears to have no interest in constructing and operating reprocessing facilities now, since reprocessing may not become economical until sometime in the next decade, at the earliest.

Even if the Allied General Nuclear Services (AGNS) reprocessing plant at Barnwell, S.C., began reprocessing operations at its projected full capacity of 1,500 tonnes per year in the early 1990's, it would at most be able to handle only the expected overflow of spent fuel from existing basins. It could not handle the total annual discharges from reactors expected to be in operation at that time. It would take one such plant over 25 years to eliminate the backlog of spent fuel that would have accumulated in reactor basins by that time. Because of the high cost of such plants and the very uncertain market for the uranium and plutonium recovered from spent fuel, it appears unlikely that the plants will be constructed on a reliable schedule by either the private sector or the Federal Government.

While a Federal waste repository would provide utilities with a way to get rid of spent fuel, a licensed, full-scale geologic repository could probably not be available before the late 1990's, leaving a need for additional spent fuel storage capacity for the interim period. DOE estimates that by 1998 over 60 reactors will need storage capacity beyond that available in their existing pools.[31] The interim period could be considerably extended if a very conservative schedule for availability of a repository were adopted (issue 2). Thus, the choice of a Federal interim spent fuel storage policy may depend significantly on the final isolation policy that is selected.

The Carter administration raised the possibility of a direct Federal role in interim spent fuel storage when it advocated that the Federal Government acquire an away-from-reactor (AFR) storage facility and offer to accept commercial spent fuel for storage until permanent disposal facilities were available. The 96th Congress did not authorize acquisition of an AFR facility, and the Reagan administration concentrated its efforts instead on helping the utilities provide their own storage capacity. The question of the appropriate Federal role in interim spent fuel storage was debated again in the 97th Congress. The following discussion evaluates the principal options considered in that debate, in light of the proposed options for providing a final isolation system considered in the preceding issues.

As background for this discussion, it is useful to understand the relationship between the two distinct storage issues considered in the 97th Congress: 1) the "AFR" issue, i.e., the question of the Federal role in interim spent fuel storage, and 2) the "MRS" issue, i.e., the question of whether the Federal Government should construct MRS facilities designed to store spent fuel and high-level waste for a long and perhaps indefinite period.

The distinction between these two concepts is not clear. An MRS has generally been thought of as being located away from reactor sites, and thus could be considered an AFR. Similarly, any storage facility, even if intended only for interim storage, as contemplated for AFRs, would be monitored and retrievable, and thus could be considered an MRS. Furthermore, it is possible that the same type of storage technology—metal casks or drywells—would be used in either case.[32]

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[31] Ibid., table C-3, pp. 73-76.

[32] See Rasmussen, op. cit., which evaluates casks and drywells for both interim storage and monitored retrievable storage.

Finally, there is some overlap in intended function in that proponents of a Federal AFR argued that it would provide some flexibility in the event of slippages of the geologic repository schedule—one of the arguments for a Federal MRS facility.

The principal difference is that the AFR debate has tended to focus on the question of providing additional storage capacity until a geologic repository is available, with emphasis on the near-term problem of providing such storage in time to prevent reactor shutdowns. In contrast, the MRS debate has focused on the longer-term questions of whether to provide Federal storage facilities either as an alternative to rapid development of geologic repositories (considered in issue 1) or as a backup in case of slippage in the repository program (discussed in the chapter 6). Since a full-scale MRS facility could probably not be designed, sited, licensed, and constructed before 1994 or 1995,[33] such a facility would not address the immediate problems of the utilities which will exhaust the capacity of their reactor basins before then—the more immediate focus of the AFR debate.

The following discussion will concentrate on the interim storage questions raised in the AFR debate, while the question of the role of MRS facilities as a backup in case of slippages in the repository program is discussed in chapter 6.

OPTION:
1. *No Federal role in interim storage; complete responsibility of private industry.*
2. *Federal assistance to private storage efforts by reducing legal obstacles; speeding the licensing process; and accelerating research, development, and demonstration of new storage technologies.*
3. *Federal provision of a limited amount of storage capacity for emergency use only.*
4. *Federal storage capacity as an alternative to construction of new storage facilities by utilities.*

The Debate

OPTION 1:

No Federal role in interim storage; complete responsibility of private industry.

In 1982, DOE analysis of utility-provided data showed that conventional reracking could meet all utility storage needs until 1986 or 1987 if transshipment were allowed.[34] The need for additional storage could be deferred several more years if reactors did not maintain full core reserve—the amount of space needed to discharge the entire reactor core—although this would involve some risk of extended shutdown if the core had to be removed for maintenance or repairs. Moreover, it appears that new water basins or other new storage technologies could be constructed at reactors by 1988, perhaps sooner, if begun in 1981 or 1982 (when the AFR issue was being debated).[35]

Thus, it appears theoretically possible that even with no Federal action, no reactor would have to shut down for lack of spent fuel storage capacity. There are, however, two important cautions in this conclusion. First, although several of the new storage technologies, especially casks, have the potential for faster implementation than conventional water basins, they will not be realistic alternatives for most utilities facing immediate storage decisions until their technical feasibility and their ability to be licensed have been demonstrated.

Second, it is not known whether the private sector will receive timely permission for constructing and operating any new spent fuel storage facilities, or even for reracking or transshipment. The primary potential sources of delays are complications in the licensing process and State and local laws and regulations that limit the quantity of fuel that can be stored at a reactor. Previously, such factors have not adversely affected reactor operations, although there appears to be considerable concern among utilities that this could be a serious problem in the future, particularly with new technologies for which there is no licensing experience. This concern underlies the utilities' desire for a Federal AFR facility, since many believe that the Federal Government will be better able to provide additional storage capacity in the face of opposition than utilities could.

One drawback is the concern that interim storage might become de facto permanent storage because of the uncertain status of spent fuel. Thus, adoption of a very conservative or open-ended schedule for availability of a Federal waste repository may make it more difficult for utilities to provide additional interim storage capacity on their own than would a program that included a fixed schedule for a repository.

OPTION 2:

Federal assistance to private storage efforts by reducing legal obstacles; speeding the licensing process; and accelerating research, development, and demonstration of new storage technologies.

Several Federal actions could help utilities provide adequate spent fuel storage capacity in time to prevent reactor shutdowns. One would be Federal support of an accelerated program for rapidly developing new dry storage technologies and demonstrating their ability to be licensed for use at reactor sites. Many utilities may prefer to stick with proven technology—water basins with conventional reracking—for providing new storage capacity, even though the likelihood that at least some of the new technologies will prove acceptable appears high. However, one large utility, the Tennessee Valley Authority (TVA), is already planning to demonstrate some of the new technologies—rod compaction and dry storage—in the next few years before it commits to the construction of new interim storage facilities.

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[33] Ibid., p. 6.2.

[34] DOE, *Spent Fuel Storage Requirements*, DOE/RL-82-1, June 1982. An update of that analysis in 1983 reached the same conclusion, although it identified one reactor that might need 13 tonnes of additional storage in 1984—DOE, *Spent Fuel Storage Requirements*, 1983, op. cit.

[35] E. R. Johnson Associates, Inc., *A Preliminary Assessment of Alternative Dry Storage Methods for the Storage of Commercial Spent Nuclear Fuel*, JAI-180 (DOE/ET/47929-1), November 1981, table 7-1, p. 7-3.

The availability of these technologies for general use by utilities might be significantly accelerated by an aggressive Federal research, development, and demonstration program to resolve remaining technical and economic questions and to share some of the costs of licensed demonstrations.

Approval of interim storage capacity might be hastened by an explicit statement of congressional intent about interim storage in existing or new storage facilities. Such a statement might speed the resolution of questions of Federal preeminence over State and local restrictions on spent fuel storage.

Adoption of a firm, credible schedule for the availability of a final isolation facility could reduce both the opposition to utilities' efforts to provide their own interim storage facilities and the financial risks created by the uncertainty about how long such facilities would be needed. Potential problems might be further lessened by a favorable resolution of NRC's ongoing generic confidence proceeding about the timely ultimate disposal of spent fuel and about the safety of continued storage until disposal is available. The proceeding was initiated precisely because of objections to provision of indefinite interim storage.[36]

OPTION 3:

Federal provision of a limited amount of storage capacity for emergency use only.

Although it is possible that utilities will be able to provide all their own interim storage capacity, it is not certain that all would be able to do so before their existing storage capacity is exhausted. Thus an argument can be made for providing some Federal storage capacity as a last-resort backup to prevent unavoidable reactor shutdowns while utilities construct their own new storage capacity. The need for such capacity depends on the importance attached to avoiding the risk of shutdowns and the associated economic costs of providing replacement power.

The amount of Federal storage needed as a last resort backup to utilities' storage programs could be much smaller than would be needed if Federal storage were intended to handle all spent fuel storage in excess of the capacity of existing basins. The major source of demand for emergency capacity would probably occur in the late 1980's and early 1990's as a result of possible delays in bringing new storage facilities online. Only 1,000 tonnes of storage, approximately the lifetime capacity needed for a 1-GWe reactor, would be required to give every one of the 24 reactors projected to need new storage capacity before 1990 an additional 2 years to provide that capacity themselves.[37]

However, if Federal storage were used as a substitute for additional utility storage, rather than a backup in case of delays in utilities' efforts, about 5,000 tonnes of Federal storage would be needed to handle the needs of those same 24 reactors until 1998, the target date for operation of a geologic repository established by NWPA.[38] Of course, provision of limited Federal storage capacity for emergency use only would not deal with the utilities' long-term problem of liability for growing inventories of spent fuel, and thus might be more compatible with a fixed schedule for a Federal waste repository, which would solve that problem, than with a flexible or indefinite schedule.

A clear decision to provide Federal storage facilities for use only in emergency cases would demonstrate to utilities that they must immediately begin planning to provide their own facilities. Any possibility that the Federal Government might later provide an alternative to construction of new facilities by utilities could encourage them to defer action and could also discourage private efforts to develop new storage technologies.

To prevent Federal emergency storage capacity from dampening utility efforts to provide storage, several actions could be taken. First, utilities could be required to show that they have made their best effort to provide their own storage. Second, existence of State or local prohibitions on increased storage could be disallowed as a justification for use of the Federal storage option, thereby facing the affected communities with the choice of shutting down a reactor or allowing increased storage.

Several options for providing Federal storage capacity may be available in the next decade. The most readily available appears to be use of modular dry storage (casks or drywells) at existing Federal facilities on

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[36] In August 1984, NRC issued a final rule embodying the results of the waste confidence proceeding, in which it stated that "there is reasonable assurance that one or more mined geologic repositories for commercial high-level radioactive waste and spent fuel will be available by the years 2007-2009," and that in any case, spent fuel could safety be stored at either reactor sites or offsite for up to 30 years after the expiration of the reactor's operating license. *Federal Register*, vol. 49, No. 171, Aug. 31, 1984, p. 34659-34660.

[37] DOE, *Spent Fuel Storage Requirements*, 1983, table C-1, p. 65.

[38] Ibid., table C-3, pp. 73-76.

Federal reservations. Availability of space in Federal facilities could enable deferral of acquisition of other facilities for several years, allowing questions about the availability of new storage technologies for utility use to be resolved and permitting a more accurate estimate of the needs for Federal storage. While these facilities would probably not be licensed, they could be available quickly.

Federal acquisition of existing private facilities with storage basins has also been considered.[39]

OPTION 4:

Federal storage capacity as an alternative to construction of new storage facilities by utilities.

An offer to accept spent fuel at a Federal AFR facility would be an effective alternative for reducing the utilities' open-ended liability for spent fuel if the availability of final isolation facilities remains uncertain. However, several objections have been made to providing such a facility for this purpose. Some argue that the Government should not subsidize nuclear power by removing the burden of uncertainty about interim storage from the generators and users of nuclear electricity, which is a commercial responsibility. In addition, some object that a Federal AFR facility could take the pressure off Government and industry to decide whether and when to develop disposal capacity.

In support of this option, it can be argued that since the Federal Government has the responsibility to provide for permanent isolation of high-level radioactive waste and is itself directly responsible for the delays and uncertainties about providing this service, it has an obligation to the users of nuclear power to share the burden of spent fuel storage created by its own inaction.

Provision of an open-ended Federal interim storage capacity is the storage option most compatible with continued flexibility about the date of availability of a permanent repository. However, the amount of spent fuel moved to Federal interim facilities could increase rapidly if the availability of final isolation sites is deferred much beyond the turn of the century. Thus, providing Federal spent fuel storage capacity as an alternative to constructing new facilities by utilities may lead to an increasing amount of spent fuel being stored at AFR interim sites, since it appears that utilities, left to their own devices, may have an economic incentive to provide additional capacity at reactor sites, if possible.[40] There would be several effects of this action.

SAFETY

NRC has concluded that spent fuel can be safely stored either at reactor sites or at AFRs.[41] The additional handling and transportation involved in AFR storage could lead to some increase in worker and public radiation exposure compared to onsite storage.

TRANSPORTATION

DOE estimates that by 1998, over 7,000 tonnes of spent fuel will require storage outside the basins of the reactors in which they were produced.[42] Interim storage of that spent fuel at sites other than those at which they were generated will increase the total amount of handling and transportation of spent fuel, and could increase the total number of communities affected by radioactive waste management activities.

Movement of significant amounts of spent fuel to interim storage facilities away from the site of generation may occur before a repository is available even if the Federal Government plays no role in interim storage, because transshipment is more economically attractive than is construction of new facilities. In fact, DOE estimates that about 2,100 tonnes of the storage needed by 1998 could be met in this way.[43] (This amount could be reduced if rod consolidation—not considered in DOE's estimates of the maximum capacity of existing basins—proves to be usable at many reactors.)

However, provision of Federal AFR storage as an alternative to utility efforts once existing basins are full could more than triple the amount of spent fuel moved to interim storage before 1998.[44] In addition to increasing transportation impacts, use of a Federal AFR facility for this purpose could increase the likelihood of confrontations between the Federal Government and affected States or localities over transportation issues.

COST

Various DOE analyses of the costs of storage have concluded that federally owned facilities would be less costly to utilities than would privately owned facilities. To some extent, this is a result of the economies of scale involved in a large Federal AFR facility, an advantage that may be offset by transportation costs or the availability of less-expensive dry storage technologies for at-reactor use. To a significant extent, it is simply the result of the economics of Federal ownership. For example, DOE analyses indicate that the cost of privately owned facilities could be up to 100 percent higher than identical federally owned facilities because of the lower cost of capital for the Federal Government and because of the Government's immunity to Federal, State, and local taxes.[45]

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[39] These include the General Electric facility at Morris, Ill., which is already storing some commercial spent fuel, and the AGNS facility at Barnwell, S. C., which has an unused storage basin that could be reracked to provide 1,750 tonnes of capacity. DOE, *Spent Fuel Storage Fact Book*, DOE/NE-0005, April 1980, table 4, p. 24.

[40] As noted in ch. 3, the new modular dry storage technologies may be less expensive to implement at reactor sites, which already have handling facilities, than at a centralized site which would require new facilities.

[41] U.S. Nuclear Regulatory Commission, *Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel*, August 1979, NUREG-0575, vol. 1, p. S-3.

[42] DOE, *Spent Fuel Storage Requirements*, 1983, table 3, p. 16.

[43] Ibid. Derived from table 3.

[44] Ibid.

There has been no systematic comparison of the costs of at-reactor and AFR interim storage that includes the cost of transportation, that considers use of the new modular dry storage technologies both at reactors and at independent AFR facilities, and that uses a consistent set of financial assumptions for all facilities, regardless of ownership. However, available studies suggest that at-reactor storage using modular dry storage technologies could be less expensive than AFR storage, even without considering the additional cost of transportation to an AFR facility.[46]

Nonetheless, any conclusions about the relative costs of at-reactor and AFR storage must remain tentative until a fully consistent comparison of at-reactor and AFR options is made. Since the modular dry storage technologies may have significant cost advantages compared with water basins, whether used at reactors or away from reactors, accelerated development and licensed demonstrations of those technologies could be very useful for determining their actual costs more precisely.

EQUITY CONSIDERATIONS

There may be significant differences among spent fuel storage systems in the distribution of their impacts among the private sector, the Federal Government, and various regions of the country. For example, with an at-reactor storage system, the health and safety risks and social impacts of storage are distributed among communities that have presumably benefited directly from the electricity generated by the spent fuel. These same communities would have to bear the costs of reactor shutdowns if additional storage space were not provided.

With an AFR system, the risks and impacts of storage are localized to those few communities in the vicinity of the AFR facility, which may or may not have benefited from the electricity generated by the spent fuel. Many additional communities would be affected by increased spent fuel transportation to the AFR facility. As a result of such distributional effects, provision by the Federal Government of a significant amount of AFR storage capacity as an alternative to utility provision of new storage facilities raises more equity considerations than do the options for Federal involvement which have less direct effect on the location of storage. As noted in chapter 4, such considerations have played an important role in debates about radioactive waste management issues.

ASSURANCE OF STORAGE CAPACITY

Reliance of utilities on the Federal Government for provision of a significant portion of their interim storage needs could increase the vulnerability of the storage system to failures. Analysis by DOE shows that by 1998, over 60 of the currently operating reactors could be relying on a Federal AFR facility for storage.[47] In this situation, any licensing delays, failures in acquiring additional AFR capacity, shutdowns of an AFR facility because of accidents or sabotage, or serious transportation problems could make many reactors vulnerable to potential shutdowns simultaneously. In contrast, a storage system in which utilities provide lifetime interim storage onsite, which would be encouraged by limiting Federal storage to backup use only, would completely insulate the utility and its ratepayers from any bottlenecks or failures elsewhere in the spent fuel storage and waste management system.

The Resolution

The NWPA incorporated a combination of options 2 and 3. Utilities are given the primary responsibility for providing the additional spent fuel storage needed until a Federal repository is available. To assist utilities in this effort, the Act provides for an accelerated program for licensed demonstrations of new storage technologies and encourages generic licensing of such technologies when possible. At the same time, the Act provides for a limited amount (1,900 tonnes) of last-resort Federal storage in existing Federal facilities, with NRC to make the determination about which utilities are entitled to use that storage. Federal acquisition of existing private facilities for spent fuel storage was not authorized.

Appendix Note

The original Atomic Energy Act made no reference to either radioactive waste or to waste disposal. The first formal regulations on the subject were promulgated by the Atomic Energy Commission in 1970 (Appendix F to Part 50 of Title 10 of the Code of Federal Regulations). These regulations required liquid high-level waste produced by reprocessing of spent fuel to be solidified and delivered to a Federal repository within 10 years of reprocessing, at which time the industry would pay a fee calculated to cover the costs of "disposal and perpetual surveillance." While the regulations distinguish between temporary storage, which can take place on privately owned property, and disposal, which can take place only on federally owned and controlled land, there is no clear definition of either term, and the reference to perpetual surveillance suggests that "disposal" could be interpreted to mean permanent storage.

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[45] DOE, *Technology for Commercial Radioactive Waste Management*, DOE/ET-0028, May 1979, vol. 3, p. 5.7.55.

[46] E. R. Johnson Associates, op. cit., estimated that the cost of at-reactor storage using surface drywells could be as low as $117 per kilogram of spent fuel. DOE, *The Monitored Retrievable Storage Concept*, p. 2-6, concluded that storage in a centralized privately financed 10,000-tonne drywell facility could cost from $100 to $170 per kilogram, with $160 per kilogram as the estimated fee based on the set of assumptions judged most likely to be accepted. Transportation from the reactor to an AFR could add around $16 per kilogram to this amount (table 2-4, p. 2-22). See also chapter note 1 in ch. 6.

[47] DOE, *Spent Fuel Storage Requirements*, 1983, table C-3, pp. 73-74.

It should be noted, however, that the Atomic Energy Commission, in proposing the Retrievable Surface Storage Facility, did distinguish between storage and disposal in terms of the continued human control and maintenance that is required for storage but not for permanent disposal.[48]

The Energy Reorganization Act of 1974 (Public Law 93-438), which split the functions of the Atomic Energy Commission between the Nuclear Regulatory Commission and the Energy Research and Development Administration (ERDA), gave the new NRC the licensing and regulatory authority over ERDA facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under the act [Sec. 202(3)] and over Retrievable Surface Storage Facilities and other facilities authorized explicitly for subsequent long-term storage of high-level radioactive waste generated by ERDA, which are not used for or part of research and development activities [Sec. 202(4)]. These sections, which form the basis for NRC's licensing authority, make no references to disposal facilities and do not define storage.

NRC has interpreted storage to include disposal, which it takes to mean emplacement of waste with no intention to retrieve. However, this definition is silent on the accepability of a requirement for continued institutional control, since emplacement with no intention to retrieve could be effected in a storage facility that nonetheless required control to ensure safety. NRC has so far applied the term *disposal* only to geologic disposal facilities and has developed regulations only for such facilities.

Finally, the Department of Energy Organization Act (Public Law 95-91, August 1977, 91 Stat. 565) explicitly gave the new DOE responsibilities for "the establishment of temporary and permanent facilities for storage, management, and ultimate disposal of nuclear wastes" [Title 42, Ch. 84, Sec. 7133. (8)(C)], and "establishment of programs for the treatment, management, storage, and disposal of nuclear wastes" [Sec. 7133 (8)(E)]. However, once again no definitions were given for storage and disposal, and the statement in (8)(C) can be read as allowing for permanent storage facilities. In addition, section 7133 (8)(F) gives DOE authority to establish fees or user charges only for nuclear waste treatment or storage facilities and makes no mention of disposal facilities, thus perpetuating the confusion between the two concepts.

The Nuclear Waste Policy Act of 1982 (Public Law 97-425) clarified the distinction by defining disposal as emplacement of waste in a repository with no foreseeable intent of recovery, and also defining a repository as a system for permanent deep geologic disposal. Since deep geologic repositories are designed not to rely on long-term institutional control and maintenance, this definition implicitly incorporates the idea that disposal does not require such continued care.

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[48] U.S. Atomic Energy Commission, op. cit., pp. 1.2-11,12; and p. 2.3-21.

Appendix C

The Nuclear Waste Policy Act of 1982

Public Law 97-425
97th Congress

An Act

To provide for the development of repositories for the disposal of high-level radioactive waste and spent nuclear fuel, to establish a program of research, development, and demonstration regarding the disposal of high-level radioactive waste and spent nuclear fuel, and for other purposes.

Jan. 7, 1983
[H.R. 3809]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Nuclear Waste Policy Act of 1982.
42 USC 10101 note.

SHORT TITLE AND TABLE OF CONTENTS

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DEFINITIONS

42 USC 10101. SEC. 2. For purposes of this Act:

(1) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(2) The term "affected Indian tribe" means any Indian tribe—

(A) within whose reservation boundaries a monitored retrievable storage facility, test and evaluation facility, or a repository for high-level radioactive waste or spent fuel is proposed to be located;

(B) whose federally defined possessory or usage rights to other lands outside of the reservation's boundaries arising out of congressionally ratified treaties may be substantially and adversely affected by the locating of such a facility: *Provided,* That the Secretary of the Interior finds, upon the petition of the appropriate governmental officials of the tribe, that such effects are both substantial and adverse to the tribe;

(3) The term "atomic energy defense activity" means any activity of the Secretary performed in whole or in part in carrying out any of the following functions:

(A) naval reactors development;

(B) weapons activities including defense inertial confinement fusion;

(C) verification and control technology;

(D) defense nuclear materials production;

(E) defense nuclear waste and materials by-products management;

(F) defense nuclear materials security and safeguards and security investigations; and

(G) defense research and development.

(4) The term "candidate site" means an area, within a geologic and hydrologic system, that is recommended by the Secretary under section 112 for site characterization, approved by the President under section 112 for site characterization, or undergoing site characterization under section 113.

(5) The term "civilian nuclear activity" means any atomic energy activity other than an atomic energy defense activity.

(6) The term "civilian nuclear power reactor" means a civilian nuclear powerplant required to be licensed under section 103 or 104 b. of the Atomic Energy Act of 1954 (42 U.S.C. 2133, 2134(b)).

(7) The term "Commission" means the Nuclear Regulatory Commission.

(8) The term "Department" means the Department of Energy.

(9) The term "disposal" means the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste.

(10) The terms "disposal package" and "package" mean the primary container that holds, and is in contact with, solidified high-level radioactive waste, spent nuclear fuel, or other radioactive materials, and any overpacks that are emplaced at a repository.

(11) The term "engineered barriers" means manmade components of a disposal system designed to prevent the release of radionuclides into the geologic medium involved. Such term includes the high-level radioactive waste form, high-level radioactive waste canisters, and other materials placed over and around such canisters.

(12) The term "high-level radioactive waste" means—

(A) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and

(B) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation.

(13) The term "Federal agency" means any Executive agency, as defined in section 105 of title 5, United States Code.

(14) The term "Governor" means the chief executive officer of a State.

(15) The term "Indian tribe" means any Indian tribe, band, nation, or other organized group or community of Indians recognized as eligible for the services provided to Indians by the Secretary of the Interior because of their status as Indians, including any Alaska Native village, as defined in section 3(c) of the Alaska Native Claims Settlement Act (43 U.S.C. 1602(c)).

(16) The term "low-level radioactive waste" means radioactive material that—

(A) is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or by-product material as defined in section 11e(2) of the Atomic Energy Act of 1954 (42 U.S.C. 2014(e)(2)); and

(B) the Commission, consistent with existing law, classifies as low-level radioactive waste.

(17) The term "Office" means the Office of Civilian Radioactive Waste Management established in section 305.

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(18) The term "repository" means any system licensed by the Commission that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel, whether or not such system is designed to permit the recovery, for a limited period during initial operation, of any materials placed in such system. Such term includes both surface and subsurface areas at which high-level radioactive waste and spent nuclear fuel handling activities are conducted.

(19) The term "reservation" means—

(A) any Indian reservation or dependent Indian community referred to in clause (a) or (b) of section 1151 of title 18, United States Code; or

(B) any land selected by an Alaska Native village or regional corporation under the provisions of the Alaska Native Claims Settlement Act (43 U.S.C. 1601 et seq.).

(20) The term "Secretary" means the Secretary of Energy.

(21) The term "site characterization" means—

(A) siting research activities with respect to a test and evaluation facility at a candidate site; and

(B) activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken.

(22) The term "siting research" means activities, including borings, surface excavations, shaft excavations, subsurface lateral excavations and borings, and in situ testing, to determine the suitability of a site for a test and evaluation facility.

(23) The term "spent nuclear fuel" means fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

(24) The term "State" means each of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Northern Mariana Islands, the Trust Territory of the Pacific Islands, and any other territory or possession of the United States.

(25) The term "storage" means retention of high-level radioactive waste, spent nuclear fuel, or transuranic waste with the intent to recover such waste or fuel for subsequent use, processing, or disposal.

(26) The term "Storage Fund" means the Interim Storage Fund established in section 137(c).

(27) The term "test and evaluation facility" means an at-depth, prototypic, underground cavity with subsurface lateral

excavations extending from a central shaft that is used for research and development purposes, including the development of data and experience for the safe handling and disposal of solidified high-level radioactive waste, transuranic waste, or spent nuclear fuel.

(28) The term "unit of general local government" means any borough, city, county, parish, town, township, village, or other general purpose political subdivision of a State.

(29) The term "Waste Fund" means the Nuclear Waste Fund established in section 302(c). *Post*, p. 2257.

SEPARABILITY

Sec. 3. If any provision of this Act, or the application of such provision to any person or circumstance, is held invalid, the remainder of this Act, or the application of such provision to persons or circumstances other than those as to which it is held invalid, shall not be affected thereby. 42 USC 10102.

TERRITORIES AND POSSESSIONS

Sec. 4. Nothing in this Act shall be deemed to repeal, modify, or amend the provisions of section 605 of the Act of March 12, 1980 (48 U.S.C. 1491). 42 USC 10103.

OCEAN DISPOSAL

Sec. 5. Nothing in this Act shall be deemed to affect the Marine Protection, Research, and Sanctuaries Act of 1972 (33 U.S.C. 1401 et seq.). 42 USC 10104.

LIMITATION ON SPENDING AUTHORITY

Sec. 6. The authority under this Act to incur indebtedness, or enter into contracts, obligating amounts to be expended by the Federal Government shall be effective for any fiscal year only to such extent or in such amounts as are provided in advance by appropriation Acts. 42 USC 10105.

PROTECTION OF CLASSIFIED NATIONAL SECURITY INFORMATION

Sec. 7. Nothing in this Act shall require the release or disclosure to any person or to the Commission of any classified national security information. 42 USC 10106.

APPLICABILITY

Sec. 8. (a) Atomic Energy Defense Activities.—Subject to the provisions of subsection (c), the provisions of this Act shall not apply with respect to any atomic energy defense activity or to any facility used in connection with any such activity. 42 USC 10107.

(b) Evaluation by President.—(1) Not later than 2 years after the date of the enactment of this Act, the President shall evaluate the use of disposal capacity at one or more repositories to be developed under subtitle A of title I for the disposal of high-level radioactive waste resulting from atomic energy defense activities. Such evaluation shall take into consideration factors relating to cost *Post*, p. 2207.

efficiency, health and safety, regulation, transportation, public acceptability, and national security.

(2) Unless the President finds, after conducting the evaluation required in paragraph (1), that the development of a repository for the disposal of high-level radioactive waste resulting from atomic energy defense activities only is required, taking into account all of the factors described in such subsection, the Secretary shall proceed promptly with arrangement for the use of one or more of the repositories to be developed under subtitle A of title I for the disposal of such waste. *Post*, p. 2207. Such arrangements shall include the allocation of costs of developing, constructing, and operating this repository or repositories. The costs resulting from permanent disposal of high-level radioactive waste from atomic energy defense activities shall be paid by the Federal Government, into the special account established under section 302. *Post*, p. 2257.

(3) Any repository for the disposal of high-level radioactive waste resulting from atomic energy defense activities only shall (A) be subject to licensing under section 202 of the Energy Reorganization Act of 1973 (42 U.S.C. 5842); and (B) comply with all requirements of the Commission for the siting, development, construction, and operation of a repository.

(c) Applicability to Certain Repositories.—The provisions of this Act shall apply with respect to any repository not used exclusively for the disposal of high-level radioactive waste or spent nuclear fuel resulting from atomic energy defense activities, research and development activities of the Secretary, or both.

APPLICABILITY

42 USC 10108.

Sec. 9. Transportation.—Nothing in this Act shall be construed to affect Federal, State, or local laws pertaining to the transportation of spent nuclear fuel or high-level radioactive waste.

TITLE I—DISPOSAL AND STORAGE OF HIGH-LEVEL RADIOACTIVE WASTE, SPENT NUCLEAR FUEL, AND LOW-LEVEL RADIOACTIVE WASTE

STATE AND AFFECTED INDIAN TRIBE PARTICIPATION IN DEVELOPMENT OF PROPOSED REPOSITORIES FOR DEFENSE WASTE

42 USC 10121.

Sec. 101. (a) Notification to States and Affected Indian Tribes.—Notwithstanding the provisions of section 8, upon any decision by the Secretary or the President to develop a repository for the disposal of high-level radioactive waste or spent nuclear fuel resulting exclusively from atomic energy defense activities, research and development activities of the Secretary, or both, and before proceeding with any site-specific investigations with respect to such repository, the Secretary shall notify the Governor and legislature of the State in which such repository is proposed to be located, or the governing body of the affected Indian tribe on whose reservation such repository is proposed to be located, as the case may be, of such decision.

(b) Participation of States and Affected Indian Tribes.—Following the receipt of any notification under subsection (a), the State or Indian tribe involved shall be entitled, with respect to the proposed repository involved, to rights of participation and consultation identical to those provided in sections 115 through 118, except that any financial assistance authorized to be provided to such State or affected Indian tribe under section 116(c) or 118(b) shall be made from amounts appropriated to the Secretary for purposes of carrying out this section.

SUBTITLE A—REPOSITORIES FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

FINDINGS AND PURPOSES

SEC. 111. (a) FINDINGS.—The Congress finds that— 42 USC 10131.

(1) radioactive waste creates potential risks and requires safe and environmentally acceptable methods of disposal;

(2) a national problem has been created by the accumulation of (A) spent nuclear fuel from nuclear reactors; and (B) radioactive waste from (i) reprocessing of spent nuclear fuel; (ii) activities related to medical research, diagnosis, and treatment; and (iii) other sources;

(3) Federal efforts during the past 30 years to devise a permanent solution to the problems of civilian radioactive waste disposal have not been adequate;

(4) while the Federal Government has the responsibility to provide for the permanent disposal of high-level radioactive waste and such spent nuclear fuel as may be disposed of in order to protect the public health and safety and the environment, the costs of such disposal should be the responsibility of the generators and owners of such waste and spent fuel;

(5) the generators and owners of high-level radioactive waste and spent nuclear fuel have the primary responsibility to provide for, and the responsibility to pay the costs of, the interim storage of such waste and spent fuel until such waste and spent fuel is accepted by the Secretary of Energy in accordance with the provisions of this Act;

(6) State and public participation in the planning and development of repositories is essential in order to promote public confidence in the safety of disposal of such waste and spent fuel; and

(7) high-level radioactive waste and spent nuclear fuel have become major subjects of public concern, and appropriate precautions must be taken to ensure that such waste and spent fuel do not adversely affect the public health and safety and the environment for this or future generations.

(b) PURPOSES.—The purposes of this subtitle are—

(1) to establish a schedule for the siting, construction, and operation of repositories that will provide a reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository;

(2) to establish the Federal responsibility, and a definite Federal policy, for the disposal of such waste and spent fuel;

(3) to define the relationship between the Federal Government and the State governments with respect to the disposal of such waste and spent fuel; and

(4) to establish a Nuclear Waste Fund, composed of payments made by the generators and owners of such waste and spent fuel, that will ensure that the costs of carrying out activities

relating to the disposal of such waste and spent fuel will be borne by the persons responsible for generating such waste and spent fuel.

RECOMMENDATION OF CANDIDATE SITES FOR SITE CHARACTERIZATION

42 USC 10132.

SEC. 112. (a) GUIDELINES.—Not later than 180 days after the date of the enactment of this Act, the Secretary, following consultation with the Council on Environmental Quality, the Administrator of the Environmental Protection Agency, the Director of the Geological Survey, and interested Governors, and the concurrence of the Commission shall issue general guidelines for the recommendation of sites for repositories. Such guidelines shall specify detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media. Such guidelines shall specify factors that qualify or disqualify any site from development as a repository, including factors pertaining to the location of valuable natural resources, hydrology, geophysics, seismic activity, and atomic energy defense activities, proximity to water supplies, proximity to populations, the effect upon the rights of users of water, and proximity to components of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Lands. Such guidelines shall take into consideration the proximity to sites where high-level radioactive waste and spent nuclear fuel is generated or temporarily stored and the transportation and safety factors involved in moving such waste to a repository. Such guidelines shall specify population factors that will disqualify any site from development as a repository if any surface facility of such repository would be located (1) in a highly populated area; or (2) adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals. Such guidelines also shall require the Secretary to consider the cost and impact of transporting to the repository site the solidified high-level radioactive waste and spent fuel to be disposed of in the repository and the advantages of regional distribution in the siting of repositories. Such guidelines shall require the Secretary to consider the various geologic media in which sites for repositories may be located and, to the extent practicable, to recommend sites in different geologic media. The Secretary shall use guidelines established under this subsection in considering candidate sites for recommendation under subsection (b). The Secretary may revise such guidelines from time to time, consistent with the provisions of this subsection.

(b) RECOMMENDATION BY SECRETARY TO THE PRESIDENT.—(1)(A) Following the issuance of guidelines under subsection (a) and consultation with the Governors of affected States, the Secretary shall nominate at least 5 sites that he determines suitable for site characterization for selection of the first repository site.

Recommendation date.

(B) Subsequent to such nomination, the Secretary shall recommend to the President 3 of the nominated sites not later than January 1, 1985 for characterization as candidate sites.

(C) Not later than July 1, 1989, the Secretary shall nominate 5 sites, which shall include at least 3 additional sites not nominated under subparagraph (A), and recommend by such date to the President from such 5 nominated sites 3 candidate sites the Secretary determines suitable for site characterization for selection of the second repository. The Secretary may not nominate any site previously nominated under subparagraph (A), that was not recommended as a candidate site under subparagraph (B).

(D) Such recommendations under subparagraphs (B) and (C) shall be consistent with the provisions of section 305.

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Environmental assessment.

(E) Each nomination of a site under this subsection shall be accompanied by an environmental assessment, which shall include a detailed statement of the basis for such recommendation and of the probable impacts of the site characterization activities planned for such site, and a discussion of alternative activities relating to site characterization that may be undertaken to avoid such impacts. Such environmental assessment shall include—

(i) an evaluation by the Secretary as to whether such site is suitable for site characterization under the guidelines established under subsection (a);

(ii) an evaluation by the Secretary as to whether such site is suitable for development as a repository under each such guideline that does not require site characterization as a prerequisite for application of such guideline;

(iii) an evaluation by the Secretary of the effects of the site characterization activities at such site on the public health and safety and the environment;

(iv) a reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered;

(v) a description of the decision process by which such site was recommended; and

(vi) an assessment of the regional and local impacts of locating the proposed repository at such site.

Judicial review.

5 USC 701 *et seq.*

(F)(i) The issuance of any environmental assessment under this paragraph shall be considered to be a final agency action subject to judicial review in accordance with the provisions of chapter 7 of title 5, United States Code, and section 119. Such judicial review shall be limited to the sufficiency of such environmental assessment with respect to the items described in clauses (i) through (vi) of subparagraph (E).

Public availability.

(G) Each environmental assessment prepared under this paragraph shall be made available to the public.

(H) Before nominating a site, the Secretary shall notify the Governor and legislature of the State in which such site is located, or the governing body of the affected Indian tribe where such site is located, as the case may be, of such nomination and the basis for such nomination.

Hearings.

(2) Before nominating any site the Secretary shall hold public hearings in the vicinity of such site to inform the residents of the area in which such site is located of the proposed nomination of such site and to receive their comments. At such hearings, the Secretary shall also solicit and receive any recommendations of such residents with respect to issues that should be addressed in the environmental assessment described in paragraph (1) and the site characterization plan described in section 113(b)(1).

(3) In evaluating the sites nominated under this section prior to any decision to recommend a site as a candidate site, the Secretary shall use available geophysical, geologic, geochemical and hydrologic, and other information and shall not conduct any preliminary borings or excavations at a site unless (i) such preliminary boring or excavation activities were in progress upon the date of enactment of this Act or (ii) the Secretary certifies that such available informa-

tion from other sources, in the absence of preliminary borings or excavations, will not be adequate to satisfy applicable requirements of this Act or any other law: *Provided,* That preliminary borings or excavations under this section shall not exceed a diameter of 6 inches.

(c) Presidential Review of Recommended Candidate Sites.—(1) The President shall review each candidate site recommendation made by the Secretary under subsection (b). Not later than 60 days after the submission by the Secretary of a recommendation of a candidate site, the President, in his discretion, may either approve or disapprove such candidate site, and shall transmit any such decision to the Secretary and to either the Governor and legislature of the State in which such candidate site is located, or the governing body of the affected Indian tribe where such candidate site is located, as the case may be. If, during such 60-day period, the President fails to approve or disapprove such candidate site, or fails to invoke his authority under paragraph (2) to delay his decision, such candidate site shall be considered to be approved, and the Secretary shall notify such Governor and legislature, or governing body of the affected Indian tribe, of the approval of such candidate site by reason of the inaction of the President.

Decision transmittal or notification.

(2) The President may delay for not more than 6 months his decision under paragraph (1) to approve or disapprove a candidate site, upon determining that the information provided with the recommendation of the Secretary is insufficient to permit a decision within the 60-day period referred to in paragraph (1). The President may invoke his authority under this paragraph by submitting written notice to the Congress, within such 60-day period, of his intent to invoke such authority. If the President invokes such authority, but fails to approve or disapprove the candidate site involved by the end of such 6-month period, such candidate site shall be considered to be approved, and the Secretary shall notify such Governor and legislature, or governing body of the affected Indian tribe, of the approval of such candidate site by reason of the inaction of the President.

(d) Continuation of Candidate Site Screening.—After the required recommendation of candidate sites under subsection (b), the Secretary may continue, as he determines necessary, to identify and study other sites to determine their suitability for recommendation for site characterization, in accordance with the procedures described in this section.

(e) Preliminary Activities.—Except as otherwise provided in this section, each activity of the President or the Secretary under this section shall be considered to be a preliminary decisionmaking activity. No such activity shall require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)), or to require any environmental review under subparagraph (E) or (F) of section 102(2) of such Act.

(f) Timely Site Characterization.—Nothing in this section may be construed as prohibiting the Secretary from continuing ongoing or presently planned site characterization at any site on Department of Energy land for which the location of the principal borehole has been approved by the Secretary by August 1, 1982, except that (1) the environmental assessment described in subsection (b)(1) shall be prepared and made available to the public before proceeding to sink shafts at any such site; and (2) the Secretary shall not continue site characterization at any such site unless such site is among the candidate sites recommended by the Secretary under the first sentence of subsection (b) for site characterization and approved by the President under subsection (c); and (3) the Secretary shall conduct public hearings under 113(b)(2) and comply with requirements under section 117 of this Act within one year of the date of enactment. Hearings.

SITE CHARACTERIZATION

42 USC 10133.

SEC. 113. (a) IN GENERAL.—The Secretary shall carry out, in accordance with the provisions of this section, appropriate site characterization activities beginning with the candidate sites that have been approved under section 112 and are located in various geologic media. The Secretary shall consider fully the comments received under subsection (b)(2) and section 112(b)(2) and shall, to the maximum extent practicable and in consultation with the Governor of the State involved or the governing body of the affected Indian tribe involved, conduct site characterization activities in a manner that minimizes any significant adverse environmental impacts identified in such comments or in the environmental assessment submitted under subsection (b)(1).

Plan submittal, review and comment.

(b) COMMISSION AND STATES.—(1) Before proceeding to sink shafts at any candidate site, the Secretary shall submit for such candidate site to the Commission and to either the Governor and legislature of the State in which such candidate site is located, or the governing body of the affected Indian tribe on whose reservation such candidate site is located, as the case may be, for their review and comment—

(A) a general plan for site characterization activities to be conducted at such candidate site, which plan shall include—

(i) a description of such candidate site;

(ii) a description of such site characterization activities, including the following: the extent of planned excavations, plans for any onsite testing with radioactive or nonradioactive material, plans for any investigation activities that may affect the capability of such candidate site to isolate high-level radioactive waste and spent nuclear fuel, and plans to control any adverse, safety-related impacts from such site characterization activities;

(iii) plans for the decontamination and decommissioning of such candidate site, and for the mitigation of any significant adverse environmental impacts caused by site characterization activities if it is determined unsuitable for application for a construction authorization for a repository;

(iv) criteria to be used to determine the suitability of such candidate site for the location of a repository, developed pursuant to section 112(a); and

(v) any other information required by the Commission;

(B) a description of the possible form or packaging for the high-level radioactive waste and spent nuclear fuel to be emplaced in such repository, a description, to the extent practicable, of the relationship between such waste form or packaging and the geologic medium of such site, and a description of the activities being conducted by the Secretary with respect to such possible waste form or packaging or such relationship; and

(C) a conceptual repository design that takes into account likely site-specific requirements.

Public availability; hearings.

(2) Before proceeding to sink shafts at any candidate site, the Secretary shall (A) make available to the public the site characterization plan described in paragraph (1); and (B) hold public hearings in the vicinity of such candidate site to inform the residents of the area in which such candidate site is located of such plan, and to receive their comments.

Report.

(3) During the conduct of site characterization activities at a candidate site, the Secretary shall report not less than once every 6 months to the Commission and to either the Governor and legislature of the State in which such candidate site is located, or the governing body of the affected Indian tribe where such candidate site is located, as the case may be, on the nature and extent of such activities and the information developed from such activities.

(c) Restrictions.—(1) The Secretary may conduct at any candidate site only such site characterization activities as the Secretary considers necessary to provide the data required for evaluation of the suitability of such candidate site for an application to be submitted to the Commission for a construction authorization for a repository at such candidate site, and for compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.).

(2) In conducting site characterization activities—

(A) the Secretary may not use any radioactive material at a candidate site unless the Commission concurs that such use is necessary to provide data for the preparation of the required environmental reports and an application for a construction authorization for a repository at such candidate site; and

(B) if any radioactive material is used at a candidate site—

(i) the Secretary shall use the minimum quantity necessary to determine the suitability of such candidate site for a repository, but in no event more than the curie equivalent of 10 metric tons of spent nuclear fuel; and

(ii) such radioactive material shall be fully retrievable.

Notification of site termination.

(3) If site characterization activities are terminated at a candidate site for any reason, the Secretary shall (A) notify the Congress, the Governors and legislatures of all States in which candidate sites are located, and the governing bodies of all affected Indian tribes where candidate sites are located, of such termination and the reasons for such termination; and (B) remove any high-level radioactive waste, spent nuclear fuel, or other radioactive materials at or in such candidate site as promptly as practicable.

(4) If a site is determined to be unsuitable for application for a construction authorization for a repository, the Secretary shall take reasonable and necessary steps to reclaim the site and to mitigate any significant adverse environmental impacts caused by site characterization activities.

(d) Preliminary Activities.—Each activity of the Secretary under this section that is in compliance with the provisions of subsection (c) shall be considered a preliminary decisionmaking activity. No such activity shall require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)), or to require any environmental review under subparagraph (E) or (F) of section 102(2) of such Act.

SITE APPROVAL AND CONSTRUCTION AUTHORIZATION

42 USC 10134.

SEC. 114. (a) HEARINGS AND PRESIDENTIAL RECOMMENDATION.—(1) The Secretary shall hold public hearings in the vicinity of each site under consideration for recommendation to the President under this paragraph as a site for the development of a repository, for the purposes of informing the residents of the area in which such site is located of such consideration and receiving their comments regarding the possible recommendation of such site. If, upon completion of such hearings and completion of site characterization activities at not less than 3 candidate sites for the first proposed repository, or from all of the characterized sites for the development of subsequent respositories, under section 113, the Secretary decides to recommend approval of such site to the President, the Secretary shall notify the Governor and legislature of the State in which such site is located, or the governing body of the affected Indian tribe where such site is located, as the case may be, of such decision. No sooner than the expiration of the 30-day period following such notification, the Secretary shall submit to the President a recommendation that the President approve such site for the development of a repository. Any such recommendation by the Secretary shall be based on the record of information developed by the Secretary under section 113 and this section, including the information described in subparagraph (A) through subparagraph (G). In making site recommendations and approvals subsequent to the first site recommendation, the Secretary and the President, respectively, shall also consider the need for regional distribution of repositories and the need to minimize, to the extent practicable, the impacts and cost of transporting spent fuel and solidified high-level radioactive waste. Together with any recommendation of a site under this paragraph, the Secretary shall make available to the public, and submit to the President, a comprehensive statement of the basis of such recommendation, including the following:

Notification of decision.

Public availability.

(A) a description of the proposed repository, including preliminary engineering specifications for the facility;

(B) a description of the waste form or packaging proposed for use at such repository, and an explanation of the relationship between such waste form or packaging and the geologic medium of such site;

(C) a discussion of data, obtained in site characterization activities, relating to the safety of such site;

(D) a final environmental impact statement prepared pursuant to subsection (f) and the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.), including an analysis of the consideration given by the Secretary to not less than 3 candidate sites for the first proposed respository or to all of the characterized sites for the development of subsequent repositories, with respect to which site characterization is completed under section 113, together with comments made concerning such environmental impact statement by the Secretary of the Interior, the Council on Environmental Quality, the Administrator, and the Commission, except that any such environmental impact statement concerning the first repository to be developed under this Act shall not be required to consider the need for a repository or the alternatives to geologic disposal;

(E) preliminary comments of the Commission concerning the extent to which the at-depth site characterization analysis and the waste form proposal for such site seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of such site as a repository;

(F) the views and comments of the Governor and legislature of any State, or the governing body of any affected Indian tribe, as determined by the Secretary, together with the response of the Secretary to such views;

(G) such other information as the Secretary considers appropriate; and

(H) any impact report submitted under section 116(c)(2)(B) by the State in which such site is located, or under section 118(b)(3)(B) by the affected Indian tribe where such site is located, as the case may be.

Submittal to Congress.

(2)(A) Not later than March 31, 1987, the President shall submit to the Congress a recommendation of one site from the three sites initially characterized that the President considers qualified for application for a construction authorization for a repository. Not later than March 31, 1990, the President shall submit to the Congress a recommendation of a second site from any sites already characterized that the President considers qualified for a construction authorization for a second repository. The President shall submit with such recommendation a copy of the report for such site prepared by the Secretary under paragraph (1). After submission of the second such recommendation, the President may submit to the Congress recommendations for other sites, in accorance with the provisions of this subtitle.

Deadlines, extensions.

(B) The President may extend the deadlines described in subparagraph (A) by not more than 12 months if, before March 31, 1986, for the first site, and March 31, 1989, for the second site, (i) the President determines that such extension is necessary; and (ii) transmits to the Congress a report setting forth the reasons for such extension.

Submittal to Congress.

(3) If approval of any such site recommendation does not take effect as a result of a disapproval by the Governor or legislature of a State under section 116 or the governing body of an affected Indian tribe under section 118, the President shall submit to the Congress, not later than 1 year after the disapproval of such recommendation, a recommendation of another site for the first or subsequent repository.

(4)(A) The President may not recommend the approval of any site under this subsection unless the Secretary has recommended to the President under paragraph (1) approval of such site and has submitted to the President a report for such site as required under such paragraph.

(B) No recommendation of a site by the President under this subsection shall require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)), or to require any environmental review under subparagraph (E) or (F) of section 102(2) of such Act.

(b) SUBMISSION OF APPLICATION.—If the President recommends to the Congress a site for ~~a repository under~~ subsection (a) and the site designation is permitted to take effect under section 115, the Secretary shall submit to the Commission an application for a construction authorization for a repository at such site not later than 90 days after the date on which the recommendation of the site designation is effective under such section and shall provide to the Governor and legislature of the State in which such site is located, or the governing body of the affected Indian tribe where such site is located, as the case may be, a copy of such application.

(c) STATUS REPORT ON APPLICATION.—Not later than 1 year after the date on which an application for a construction authorization is submitted under subsection (b), and annually thereafter until the date on which such authorization is granted, the Commission shall submit a report to the Congress describing the proceedings undertaken through the date of such report with regard to such application, including a description of—

(1) any major unresolved safety issues, and the explanation of the Secretary with respect to design and operation plans for resolving such issues;

(2) any matters of contention regarding such application; and

(3) any Commission actions regarding the granting or denial of such authorization.

Construction authorization application.

(d) COMMISSION ACTION.—The Commission shall consider an application for a construction authorization for all or part of a repository in accordance with the laws applicable to such applications, except that the Commission shall issue a final decision approving or disapproving the issuance of a construction authorization not later than—

(1) January 1, 1989, for the first such application, and January 1, 1992, for the second such application; or

(2) the expiration of 3 years after the date of the submission of such application, except that the Commission may extend such deadline by not more than 12 months if, not less than 30 days before such deadline, the Commission complies with the reporting requirements established in subsection (e)(2);

whichever occurs later. The Commission decision approving the first such application shall prohibit the emplacement in the first repository of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel until such time as a second repository is in operation. In the event that a monitored retrievable storage facility, approved pursuant to subtitle C of this Act, shall be located, or is planned to be located, within 50 miles of the first repository, then the Commission decision approving the first such application shall prohibit the emplacement of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of spent fuel in both the repository and monitored retrievable storage facility until such time as a second repository is in operation.

(e) PROJECT DECISION SCHEDULE.—(1) The Secretary shall prepare and update, as appropriate, in cooperation with all affected Federal agencies, a project decision schedule that portrays the optimum way to attain the operation of the repository involved, within the time periods specified in this subtitle. Such schedule shall include a description of objectives and a sequence of deadlines for all Federal agencies required to take action, including an identification of the activities in which a delay in the start, or completion, of such activities will cause a delay in beginning repository operation.

Report submittal to Secretary and Congress.

(2) Any Federal agency that determines that it cannot comply with any deadline in the project decision schedule, or fails to so comply, shall submit to the Secretary and to the Congress a written report explaining the reason for its failure or expected failure to

meet such deadline, the reason why such agency could not reach an agreement with the Secretary, the estimated time for completion of the activity or activities involved, the associated effect on its other deadlines in the project decision schedule, and any recommendations it may have or actions it intends to take regarding any improvements in its operation or organization, or changes to its statutory directives or authority, so that it will be able to mitigate the delay involved. The Secretary, within 30 days after receiving any such report, shall file with the Congress his response to such report, including the reasons why the Secretary could not amend the project decision schedule to accommodate the Federal agency involved.

Report response, filing with Congress.

(f) ENVIRONMENTAL IMPACT STATEMENT.—Any recommendation made by the Secretary under this section shall be considered a major Federal action significantly affecting the quality of the human environment for purposes of the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.). A final environmental impact statement prepared by the Secretary under such Act shall accompany any recommendation to the President to approve a site for a repository. With respect to the requirements imposed by the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.), compliance with the procedures and requirements of this Act shall be deemed adequate consideration of the need for a repository, the time of the initial availability of a repository, and all alternatives to the isolation of high-level radioactive waste and spent nuclear fuel in a repository. For purposes of complying with the requirements of the National Environmental Policy Act of 1969 (42 U.S.C. 1321 et seq.) and this section, the Secretary shall consider as alternate sites for the first repository to be developed under this subtitle 3 candidate sites with respect to which (1) site characterization has been completed under section 113; and (2) the Secretary has made a preliminary determination, that such sites are suitable for development as respositories consistent with the guidelines promulgated under section 112(a). The Secretary shall consider as alternative sites for subsequent repositories at least three of the remaining sites recommended by the Secretary by January 1, 1985, and by July 1, 1989, pursuant to section 112(b) and approved by the President for site characterization pursuant to section 112(c) for which (1) site characterization has been completed under section 113; and (2) the Secretary has made a preliminary determination that such sites are suitable for development as respositories consistent with the guidelines promulgated under section 112(a). Any environmental impact statement prepared in connection with a repository proposed to be constructed by the Secretary under this subtitle shall, to the extent practicable, be adopted by the Commission in connection with the issuance by the Commission of a construction authorization and license for such repository. To the extent such statement is adopted by the Commission, such adoption shall be deemed to also satisfy the responsibilities of the Commission under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) and no further consideration shall be required, except that nothing in this subsection shall affect any independent responsibilities of the Commission to protect the public health and safety under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.). Nothing in this Act shall be construed to amend or otherwise detract from the licensing requirements of the Nucler Regulatory Commission as established in title II of the Energy Reorganization Act of 1974 (Public Law 93-438). In

42 USC 4321 *et seq.*

42 USC 5841.

any such statement prepared with respect to the first repository to be constructed under this subtitle, the need for a repository or nongeologic alternatives to the site of such repository shall not be considered.

REVIEW OF REPOSITORY SITE SELECTION

42 USC 10135.

Sec. 115. (a) Definition.—For purposes of this section, the term "resolution of repository siting approval" means a joint resolution of the Congress, the matter after the resolving clause of which is as follows: "That there hereby is approved the site at .... for a repository, with respect to which a notice of disapproval was submitted by .... on ....". The first blank space in such resolution shall be filled with the name of the geographic location of the proposed site of the repository to which such resolution pertains; the second blank space in such resolution shall be filled with the designation of the State Governor and legislature or Indian tribe governing body submitting the notice of disapproval to which such resolution pertains; and the last blank space in such resolution shall be filled with the date of such submission.

(b) State or Indian Tribe Petitions.—The designation of a site as suitable for application for a construction authorization for a repository shall be effective at the end of the 60-day period beginning on the date that the President recommends such site to the Congress under section 114, unless the Governor and legislature of the State in which such site is located, or the governing body of an Indian tribe on whose reservation such site is located, as the case may be, has submitted to the Congress a notice of disapproval under section 116 or 118. If any such notice of disapproval has been submitted, the designation of such site shall not be effective except as provided under subsection (c).

Notice of disapproval, submittal to Congress.

(c) Congressional Review of Petitions.—If any notice of disapproval of a repository site designation has been submitted to the Congress under section 116 or 118 after a recommendation for approval of such site is made by the President under section 114, such site shall be disapproved unless, during the first period of 90 calendar days of continuous session of the Congress after the date of the receipt by the Congress of such notice of disapproval, the Congress passes a resolution of repository siting approval in accordance with this subsection approving such site, and such resolution thereafter becomes law.

(d) Procedures Applicable to the Senate.—(1) The provisions of this subsection are enacted by the Congress—

(A) as an exercise of the rulemaking power of the Senate, and as such they are deemed a part of the rules of the Senate, but applicable only with respect to the procedure to be followed in the Senate in the case of resolutions of repository siting approval, and such provisions supersede other rules of the Senate only to the extent that they are inconsistent with such other rules; and

(B) with full recognition of the constitutional right of the Senate to change the rules (so far as relating to the procedure of the Senate) at any time, in the same manner and to the same extent as in the case of any other rule of the Senate.

Introduction of resolution.

(2)(A) Not later than the first day of session following the day on which any notice of disapproval of a repository site selection is submitted to the Congress under section 116 or 118, a resolution of repository siting approval shall be introduced (by request) in the Senate by the chairman of the committee to which such notice of disapproval is referred, or by a Member or Members of the Senate designated by such chairman.

Committee recommendations.

(B) Upon introduction, a resolution of repository siting approval shall be referred to the appropriate committee or committees of the Senate by the President of the Senate, and all such resolutions with respect to the same repository site shall be referred to the same committee or committees. Upon the expiration of 60 calendar days of continuous session after the introduction of the first resolution of repository siting approval with respect to any site, each committee to which such resolution was referred shall make its recommendations to the Senate.

Discharge of committee.

(3) If any committee to which is referred a resolution of siting approval introduced under paragraph (2)(A), or, in the absence of such a resolution, any other resolution of siting approval introduced with respect to the site involved, has not reported such resolution at the end of 60 days of continuous session of Congress after introduction of such resolution, such committee shall be deemed to be discharged from further consideration of such resolution, and such resolution shall be placed on the appropriate calendar of the Senate.

(4)(A) When each committee to which a resolution of siting approval has been referred has reported, or has been deemed to be discharged from further consideration of, a resolution described in paragraph (3), it shall at any time thereafter be in order (even though a previous motion to the same effect has been disagreed to) for any Member of the Senate to move to proceed to the consideration of such resolution. Such motion shall be highly privileged and shall not be debatable. Such motion shall not be subject to amendment, to a motion to postpone, or to a motion to proceed to the consideration of other business. A motion to reconsider the vote by which such motion is agreed to or disagreed to shall not be in order. If a motion to proceed to the consideration of such resolution is agreed to, such resolution shall remain the unfinished business of the Senate until disposed of.

Debate.

(B) Debate on a resolution of siting approval, and on all debatable motions and appeals in connection with such resolution, shall be limited to not more than 10 hours, which shall be divided equally between Members favoring and Members opposing such resolution. A motion further to limit debate shall be in order and shall not be debatable. Such motion shall not be subject to amendment, to a motion to postpone, or to a motion to proceed to the consideration of other business, and a motion to recommit such resolution shall not be in order. A motion to reconsider the vote by which such resolution is agreed to or disagreed to shall not be in order.

(C) Immediately following the conclusion of the debate on a resolution of siting approval, and a single quorum call at the conclusion of such debate if requested in accordance with the rules of the Senate, the vote on final approval of such resolution shall occur.

Appeals.

(D) Appeals from the decisions of the Chair relating to the application of the rules of the Senate to the procedure relating to a resolution of siting approval shall be decided without debate.

(5) If the Senate receives from the House a resolution of repository siting approval with respect to any site, then the following procedure shall apply:

(A) The resolution of the House with respect to such site shall not be referred to a committee.

(B) With respect to the resolution of the Senate with respect to such site—

(i) the procedure with respect to that or other resolutions of the Senate with respect to such site shall be the same as if no resolution from the House with respect to such site had been received; but

(ii) on any vote on final passage of a resolution of the Senate with respect to such site, a resolution from the House with respect to such site where the text is identical shall be automatically substituted for the resolution of the Senate.

(e) Procedures Applicable to the House of Representatives.—(1) The provisions of this section are enacted by the Congress—

(A) as an exercise of the rulemaking power of the House of Representatives, and as such they are deemed a part of the rules of the House, but applicable only with respect to the procedure to be followed in the House in the case of resolutions of repository siting approval, and such provisions supersede other rules of the House only to the extent that they are inconsistent with such other rules; and

(B) with full recognition of the constitutional right of the House to change the rules (so far as relating to the procedure of the House) at any time, in the same manner and to the same extent as in the case of any other rule of the House.

(2) Resolutions of repository siting approval shall upon introduction, be immediately referred by the Speaker of the House to the appropriate committee or committees of the House. Any such resolution received from the Senate shall be held at the Speaker's table.

Discharge of committee.

(3) Upon the expiration of 60 days of continuous session after the introduction of the first resolution of repository siting approval with respect to any site, each committee to which such resolution was referred shall be discharged from further consideration of such resolution, and such resolution shall be referred to the appropriate calendar, unless such resolution or an identical resolution was previously reported by each committee to which it was referred.

Resolution, consideration and debate.

(4) It shall be in order for the Speaker to recognize a Member favoring a resolution to call up a resolution of repository siting approval after it has been on the appropriate calendar for 5 legislative days. When any such resolution is called up, the House shall proceed to its immediate consideration and the Speaker shall recognize the Member calling up such resolution and a Member opposed to such resolution for 2 hours of debate in the House, to be equally divided and controlled by such Members. When such time has expired, the previous question shall be considered as ordered on the resolution to adoption without intervening motion. No amendment to any such resolution shall be in order, nor shall it be in order to move to reconsider the vote by which such resolution is agreed to or disagreed to.

(5) If the House receives from the Senate a resolution of repository siting approval with respect to any site, then the following procedure shall apply:

(A) The resolution of the Senate with respect to such site shall not be referred to a committee.

(B) With respect to the resolution of the House with respect to such site—

(i) the procedure with respect to that or other resolutions of the House with respect to such site shall be the same as if no resolution from the Senate with respect to such site had been received; but

(ii) on any vote on final passage of a resolution of the House with respect to such site, a resolution from the Senate with respect to such site where the text is identical shall be automatically substituted for the resolution of the House.

(f) COMPUTATION OF DAYS.—For purposes of this section—

(1) continuity of session of Congress is broken only by an adjournment sine die; and

(2) the days on which either House is not in session because of an adjournment of more than 3 days to a day certain are excluded in the computation of the 90-day period referred to in subsection (c) and the 60-day period referred to in subsections (d) and (e).

(g) INFORMATION PROVIDED TO CONGRESS.—In considering any notice of disapproval submitted to the Congress under section 116 or 118, the Congress may obtain any comments of the Commission with respect to such notice of disapproval. The provision of such comments by the Commission shall not be construed as binding the Commission with respect to any licensing or authorization action concerning the repository involved.

PARTICIPATION OF STATES

42 USC 10136.

SEC. 116. (a) NOTIFICATION OF STATES AND AFFECTED TRIBES.—The Secretary shall identify the States with one or more potentially acceptable sites for a repository within 90 days after the date of enactment of this Act. Within 90 days of such identification, the Secretary shall notify the Governor, the State legislature, and the tribal council of any affected Indian tribe in any State of the potentially acceptable sites within such State. For the purposes of this title, the term "potentially acceptable site" means any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the Department undertakes preliminary drilling and geophysical testing for the definition of site location.

"Potentially acceptable site."

(b) STATE PARTICIPATION IN REPOSITORY SITING DECISIONS.—(1) Unless otherwise provided by State law, the Governor or legislature of each State shall have authority to submit a notice of disapproval to the Congress under paragraph (2). In any case in which State law provides for submission of any such notice of disapproval by any other person or entity, any reference in this subtitle to the Governor or legislature of such State shall be considered to refer instead to such other person or entity.

Notice of disapproval, submittal to Congress.

(2) Upon the submission by the President to the Congress of a recommendation of a site for a repository, the Governor or legislature of the State in which such site is located may disapprove the site designation and submit to the Congress a notice of disapproval. Such Governor or legislature may submit such a notice of disapproval to the Congress not later than the 60 days after the date that the President recommends such site to the Congress under section 114. A notice of disapproval shall be considered to be submitted to the Congress on the date of the transmittal of such notice of disapproval to the Speaker of the House and the President pro tempore of the Senate. Such notice of disapproval shall be accompanied by a state-

ment of reasons explaining why such Governor or legislature disapproved the recommended repository site involved.

(3) The authority of the Governor or legislature of each State under this subsection shall not be applicable with respect to any site located on a reservation.

Grants.

(c) FINANCIAL ASSISTANCE.—(1)(A) The Secretary shall make grants to each State notified under subsection (a) for the purpose of participating in activities required by sections 116 and 117 or authorized by written agreement entered into pursuant to subsection 117(c). Any salary or travel expense that would ordinarily be incurred by such State, or by any political subdivision of such State, may not be considered eligible for funding under this paragraph.

(B) The Secretary shall make grants to each State in which a candidate site for a repository is approved under section 112(c). Such grants may be made to each such State only for purposes of enabling such State—

(i) to review activities taken under this subtitle with respect to such site for purposes of determining any potential economic, social, public health and safety, and environmental impacts of such repository on the State and its residents;

(ii) to develop a request for impact assistance under paragraph (2);

(iii) to engage in any monitoring, testing, or evaluation activities with respect to site characterization programs with regard to such site;

(iv) to provide information to its residents regarding any activities of such State, the Secretary, or the Commission with respect to such site; and

(v) to request information from, and make comments and recommendations to, the Secretary regarding any activities taken under this subtitle with respect to such site.

(C) Any salary or travel expense that would ordinarily be incurred by such State, or by any political subdivision of such State, may not be considered eligible for funding under this paragraph.

Construction authorization.

(2)(A) The Secretary shall provide financial and technical assistance to any State requesting such assistance in which there is a site with respect to which the Commission has authorized construction of a repository. Such assistance shall be designed to mitigate the impact on such State of the development of such repository. Such assistance to such State shall commence within 6 months following the granting by the Commission of a construction authorization for such repository and following the initiation of construction activities at such site.

Report submittal.

(B) Any State desiring assistance under this paragraph shall prepare and submit to the Secretary a report on any economic, social, public health and safety, and environmental impacts that are likely as a result of the development of a repository at a site in such State. Such report shall be submitted to the Secretary following the completion of site characterization activities at such site and before the recommendation of such site to the President by the Secretary for application for a construction authorization for a repository. As soon as practicable following the granting of a construction authorization for such repository, the Secretary shall seek to enter into a binding agreement with the State involved setting forth the amount of assistance to be provided to such State under this paragraph and the procedures to be followed in providing such assistance.

(3) The Secretary shall also grant to each State and unit of general local government in which a site for a repository is approved under section 112(c) an amount each fiscal year equal to the amount such State and unit of general local government, respectively, would receive were they authorized to tax site characterization activities at such site, and the development and operation of such repository, as such State and unit of general local government tax the other real property and industrial activities occurring within such State and unit of general local government. Such grants shall continue until such time as all such activities, development, and operation are terminated at such site.

Grants, limitations.

(4)(A) A State may not receive any grant under paragraph (1) after the expiration of the 1-year period following—

(i) the date on which the Secretary notifies the Governor and legislature of the State involved of the termination of site characterization activities at the candidate site involved in such State;

(ii) the date on which the site in such State is disapproved under section 115; or

(iii) the date on which the Commission disapproves an application for a construction authorization for a repository at such site;

whichever occurs first, unless there is another candidate site in the State approved under section 112(c) with respect to which the actions described in clauses (i), (ii), and (iii) have not been taken.

(B) A State may not receive any further assistance under paragraph (2) with respect to a site if repository construction activities at such site are terminated by the Secretary or if such activities are permanently enjoined by any court.

Funding limitations.

(C) At the end of the 2-year period beginning on the effective date of any license to receive and possess for a repository in a State, no Federal funds shall be made available to such State under paragraph (1) or (2), except for—

(i) such funds as may be necessary to support State activities related to any other repository located in, or proposed to be located in, such State, and for which a license to receive and possess has not been in effect for more than 1 year; and

(ii) such funds as may be necessary to support State activities pursuant to agreements or contracts for impact assistance entered into, under paragraph (2), by such State with the Secretary during such 2-year period.

(5) Financial assistance authorized in this subsection shall be made out of amounts held in the Nuclear Waste Fund established in section 302.

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(d) ADDITIONAL NOTIFICATION AND CONSULTATION.—Whenever the Secretary is required under any provision of this Act to notify or consult with the governing body of an affected Indian tribe where a site is located, the Secretary shall also notify or consult with, as the case may be, the Governor of the State in which such reservation is located.

CONSULTATION WITH STATES AND AFFECTED INDIAN TRIBES

42 USC 10137.

SEC. 117. (a) PROVISION OF INFORMATION.—(1) The Secretary, the Commission, and other agencies involved in the construction, operation, or regulation of any aspect of a repository in a State shall provide to the Governor and legislature of such State, and to the governing body of any affected Indian tribe, timely and complete information regarding determinations or plans made with respect to the site characterization siting, development, design, licensing, construction, operation, regulation, or decommissioning of such repository.

Information request, response.

(2) Upon written request for such information by the Governor or legislature of such State, or by the governing body of any affected Indian tribe, as the case may be, the Secretary shall provide a written response to such request within 30 days of the receipt of such request. Such response shall provide the information requested or, in the alternative, the reasons why the information cannot be so provided. If the Secretary fails to so respond within such 30 days, the Governor or legislature of such State, or the governing body of any affected Indian tribe, as the case may be, may transmit a formal written objection to such failure to respond to the President. If the President or Secretary fails to respond to such written request within 30 days of the receipt by the President of such formal written objection, the Secretary shall immediately suspend all activities in such State authorized by this subtitle, and shall not renew such activities until the Governor or legislature of such State, or the governing body of any affected Indian tribe, as the case may be, has received the written response to such written request required by this subsection.

(b) Consultation and Cooperation.—In performing any study of an area within a State for the purpose of determining the suitability of such area for a repository pursuant to section 112(c), and in subsequently developing and loading any repository within such State, the Secretary shall consult and cooperate with the Governor and legislature of such State and the governing body of any affected Indian tribe in an effort to resolve the concerns of such State and any affected Indian tribe regarding the public health and safety, environmental, and economic impacts of any such repository. In carrying out his duties under this subtitle, the Secretary shall take such concerns into account to the maximum extent feasible and as specified in written agreements entered into under subsection (c).

(c) Written Agreement.—Not later than 60 days after (1) the approval of a site for site characterization for such a repository under section 112(c), or (2) the written request of the State or Indian tribe in any affected State notified under section 116(a) to the Secretary, whichever, first occurs, the Secretary shall seek to enter into a binding written agreement, and shall begin negotiations, with such State and, where appropriate, to enter into a separate binding agreement with the governing body of any affected Indian tribe, setting forth (but not limited to) the procedures under which the requirements of subsections (a) and (b), and the provisions of such written agreement, shall be carried out. Any such written agreement shall not affect the authority of the Commission under existing law. Each such written agreement shall, to the maximum extent feasible, be completed not later than 6 months after such notification. If such written agreement is not completed within such period, the Secretary shall report to the Congress in writing within 30 days on the status of negotiations to develop such agreement and the reasons why such agreement has not been completed. Prior to submission of such report to the Congress, the Secretary shall transmit such report to the Governor of such State or the governing body of such affected Indian tribe, as the case may be, for their review and comments. Such comments shall be included in such

Report to Congress.

Report, review and comments.

report prior to submission to the Congress. Such written agreement shall specify procedures—

(1) by which such State or governing body of an affected Indian tribe, as the case may be, may study, determine, comment on, and make recommendations with regard to the possible public health and safety, environmental, social, and economic impacts of any such repository;

(2) by which the Secretary shall consider and respond to comments and recommendations made by such State or governing body of an affected Indian tribe, including the period in which the Secretary shall so respond;

Review and modification.

(3) by which the Secretary and such State or governing body of an affected Indian tribe may review or modify the agreement periodically;

Report.

(4) by which such State or governing body of an affected Indian tribe is to submit an impact report and request for impact assistance under section 116(c) or section 118(b), as the case may be;

(5) by which the Secretary shall assist such State, and the units of general local government in the vicinity of the repository site, in resolving the offsite concerns of such State and units of general local government, including, but not limited to, questions of State liability arising from accidents, necessary road upgrading and access to the site, ongoing emergency preparedness and emergency response, monitoring of transportation of high-level radioactive waste and spent nuclear fuel through such State, conduct of baseline health studies of inhabitants in neighboring communities near the repository site and reasonable periodic monitoring thereafter, and monitoring of the repository site upon any decommissioning and decontamination;

(6) by which the Secretary shall consult and cooperate with such State on a regular, ongoing basis and provide for an orderly process and timely schedule for State review and evaluation, including identification in the agreement of key events, milestones, and decision points in the activities of the Secretary at the potential repository site;

Transportation of radioactive waste and spent nuclear fuel, State notification.

(7) by which the Secretary shall notify such State prior to the transportation of any high-level radioactive waste and spent nuclear fuel into such State for disposal at the repository site;

Monitoring and testing.

(8) by which such State may conduct reasonable independent monitoring and testing of activities on the repository site, except that such monitoring and testing shall not unreasonably interfere with or delay onsite activities;

(9) for sharing, in accordance with applicable law, of all technical and licensing information, the utilization of available expertise, the facilitating of permit procedures, joint project review, and the formulation of joint surveillance and monitoring arrangements to carry out applicable Federal and State laws;

(10) for public notification of the procedures specified under the preceding paragraphs; and

(11) for resolving objections of a State and affected Indian tribes at any stage of the planning, siting, development, construction, operation, or closure of such a facility within such State through negotiation, arbitration, or other appropriate mechanisms.

PARTICIPATION OF INDIAN TRIBES

Notice of disapproval, submittal to Congress
42 USC 10138.

SEC. 118. (a) PARTICIPATION OF INDIAN TRIBES IN REPOSITORY SITING DECISIONS.—Upon the submission by the President to the Congress of a recommendation of a site for a repository located on the reservation of an affected Indian tribe, the governing body of such Indian tribe may disapprove the site designation and submit to the Congress a notice of disapproval. The governing body of such Indian tribe may submit such a notice of disapproval to the Congress not later than the 60 days after the date that the President recommends such site to the Congress under section 114. A notice of disapproval shall be considered to be submitted to the Congress on the date of the transmittal of such notice of disapproval to the Speaker of the House and the President pro tempore of the Senate. Such notice of disapproval shall be accompanied by a statement of reasons explaining why the governing body of such Indian tribe disapproved the recommended repository site involved.

Grants.

(b) FINANCIAL ASSISTANCE.—(1) The Secretary shall make grants to each affected tribe notified under section 116(a) for the purpose of participating in activities required by section 117 or authorized by written agreement entered into pursuant to section 117(c). Any salary or travel expense that would ordinarily be incurred by such tribe, may not be considered eligible for funding under this paragraph.

(2)(A) The Secretary shall make grants to each affected Indian tribe where a candidate site for a repository is approved under section 112(c). Such grants may be made to each such Indian tribe only for purposes of enabling such Indian tribe—

(i) to review activities taken under this subtitle with respect to such site for purposes of determining any potential economic, social, public health and safety, and environmental impacts of such repository on the reservation and its residents;

(ii) to develop a request for impact assistance under paragraph (2);

(iii) to engage in any monitoring, testing, or evaluation activities with respect to site characterization programs with regard to such site;

(iv) to provide information to the residents of its reservation regarding any activities of such Indian tribe, the Secretary, or the Commission with respect to such site; and

(v) to request information from, and make comments and recommendations to, the Secretary regarding any activities taken under this subtitle with respect to such site.

(B) The amount of funds provided to any affected Indian tribe under this paragraph in any fiscal year may not exceed 100 percent of the costs incurred by such Indian tribe with respect to the activities described in clauses (i) through (v) of subparagraph (A). Any salary or travel expense that would ordinarily be incurred by such Indian tribe may not be considered eligible for funding under this paragraph.

(3)(A) The Secretary shall provide financial and technical assistance to any affected Indian tribe requesting such assistance and where there is a site with respect to which the Commission has authorized construction of a repository. Such assistance shall be designed to mitigate the impact on such Indian tribe of the development of such repository. Such assistance to such Indian tribe shall commence within 6 months following the granting by the Commission of a construction authorization for such repository and following the initiation of construction activities at such site.

Report submittal.

(B) Any affected Indian tribe desiring assistance under this paragraph shall prepare and submit to the Secretary a report on any economic, social, public health and safety, and environmental impacts that are likely as a result of the development of a repository at a site on the reservation of such Indian tribe. Such report shall be submitted to the Secretary following the completion of site characterization activities at such site and before the recommendation of such site to the President by the Secretary for application for a construction authorization for a repository. As soon as practicable following the granting of a construction authorization for such repository, the Secretary shall seek to enter into a binding agreement with the Indian tribe involved setting forth the amount of assistance to be provided to such Indian tribe under this paragraph and the procedures to be followed in providing such assistance.

(4) The Secretary shall grant to each affected Indian tribe where a site for a repository is approved under section 112(c) an amount each fiscal year equal to the amount such Indian tribe would receive were it authorized to tax site characterization activities at such site, and the development and operation of such repository, as such Indian tribe taxes the other commercial activities occurring on such reservation. Such grants shall continue until such time as all such activities, development, and operation are terminated at such site.

Grants, limitation.

(5) An affected Indian tribe may not receive any grant under paragraph (1) after the expiration of the 1-year period following—

(i) the date on which the Secretary notifies such Indian tribe of the termination of site characterization activities at the candidate site involved on the reservation of such Indian tribe;

(ii) the date on which such site is disapproved under section 115; or

(iii) the date on which the Commission disapproves an application for a construction authorization for a repository at such site;

whichever occurs first, unless there is another candidate site on the reservation of such Indian tribe that is approved under section 112(c) and with respect to which the actions described in clauses (i), (ii), and (iii) have not been taken.

(B) An affected Indian tribe may not receive any further assistance under paragraph (2) with respect to a site if repository construction activities at such site are terminated by the Secretary or if such activities are permanently enjoined by any court.

Funding.

(C) At the end of the 2-year period beginning on the effective date of any license to receive and possess for a repository at a site on the reservation of an affected Indian tribe, no Federal funds shall be made available under paragraph (1) or (2) to such Indian tribe, except for—

(i) such funds as may be necessary to support activities of such Indian tribe related to any other repository where a license to receive and possess has not been in effect for more than 1 year; and

(ii) such funds as may be necessary to support activities of such Indian tribe pursuant to agreements or contracts for impact assistance entered into, under paragraph (2), by such Indian tribe with the Secretary during such 2-year period.

(6) Financial assistance authorized in this subsection shall be made out of amounts held in the Nuclear Waste Fund established in section 302.

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JUDICIAL REVIEW OF AGENCY ACTIONS

42 USC 10139.

SEC. 119. (a) JURISDICTION OF UNITED STATES COURTS OF APPEALS.—(1) Except for review in the Supreme Court of the United States, the United States courts of appeals shall have original and exclusive jurisdiction over any civil action—

(A) for review of any final decision or action of the Secretary, the President, or the Commission under this subtitle;

(B) alleging the failure of the Secretary, the President, or the Commission to make any decision, or take any action, required under this subtitle;

(C) challenging the constitutionality of any decision made, or action taken, under any provision of this subtitle;

(D) for review of any environmental impact statement prepared pursuant to the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) with respect to any action under this subtitle, or as required under section 135(c)(1), or alleging a failure to prepare such statement with respect to any such action;

(E) for review of any environmental assessment prepared under section 112(b)(1) or 135(c)(2); or

(F) for review of any research and development activity under title II.

Post, p. 2245.

(2) The venue of any proceeding under this section shall be in the judicial circuit in which the petitioner involved resides or has its principal office, or in the United States Court of Appeals for the District of Columbia.

(c) DEADLINE FOR COMMENCING ACTION.—A civil action for judicial review described under subsection (a)(1) may be brought not later than the 180th day after the date of the decision or action or failure to act involved, as the case may be, except that if a party shows that he did not know of the decision or action complained of (or of the failure to act), and that a reasonable person acting under the circumstances would not have known, such party may bring a civil action not later than the 180th day after the date such party acquired actual or constructive knowledge of such decision, action, or failure to act.

EXPEDITED AUTHORIZATIONS

42 USC 10140.

SEC. 120. (a) ISSUANCE OF AUTHORIZATIONS.—(1) To the extent that the taking of any action related to the site characterization of a site or the construction or initial operation of a repository under this subtitle requires a certificate, right-of-way, permit, lease, or other authorization from a Federal agency or officer, such agency or officer shall issue or grant any such authorization at the earliest practicable date, to the extent permitted by the applicable provisions of law administered by such agency or officer. All actions of a Federal agency or officer with respect to consideration of applications or requests for the issuance or grant of any such authorization shall be expedited, and any such application or request shall take precedence over any similar applications or requests not related to such repositories.

(2) The provisions of paragraph (1) shall not apply to any certificate, right-of-way, permit, lease, or other authorization issued or granted by, or requested from, the Commission.

(b) TERMS OF AUTHORIZATIONS.—Any authorization issued or granted pursuant to subsection (a) shall include such terms and conditions as may be required by law, and may include terms and conditions permitted by law.

CERTAIN STANDARDS AND CRITERIA

42 USC 10141.

SEC. 121. (a) ENVIRONMENTAL PROTECTION AGENCY STANDARDS.—Not later than 1 year after the date of the enactment of this Act, the Administrator, pursuant to authority under other provisions of law, shall, by rule, promulgate generally applicable standards for protection of the general environment from offsite releases from radioactive material in repositories.

(b) COMMISSION REQUIREMENTS AND CRITERIA.—(1)(A) Not later than January 1, 1984, the Commission, pursuant to authority under other provisions of law, shall, by rule, promulgate technical requirements and criteria that it will apply, under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) and the Energy Reorganization Act of 1974 (42 U.S.C. 5801 et seq.), in approving or disapproving—

(i) applications for authorization to construct repositories;

(ii) applications for licenses to receive and possess spent nuclear fuel and high-level radioactive waste in such repositories; and

(iii) applications for authorization for closure and decommissioning of such repositories.

(B) Such criteria shall provide for the use of a system of multiple barriers in the design of the repository and shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel emplaced in the repository as the Commission deems appropriate.

(C) Such requirements and criteria shall not be inconsistent with any comparable standards promulgated by the Administrator under subsection (a).

(2) For purposes of this Act, nothing in this section shall be construed to prohibit the Commission from promulgating requirements and criteria under paragraph (1) before the Administrator promulgates standards under subsection (a). If the Administrator promulgates standards under subsection (a) after requirements and criteria are promulgated by the Commission under paragraph (1), such requirements and criteria shall be revised by the Commission if necessary to comply with paragraph (1)(C).

(c) ENVIRONMENTAL IMPACT STATEMENT.—The promulgation of standards or criteria in accordance with the provisions of this section shall not require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)), or to require any environmental review under subparagraph (E) or (F) of section 102(2) of such Act.

DISPOSAL OF SPENT NUCLEAR FUEL

42 USC 10142.

SEC. 122. Notwithstanding any other provision of this subtitle, any repository constructed on a site approved under this subtitle shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel. The Secretary shall specify the appropriate period of retrievability with respect to any repository at the time of design of such repository, and such aspect of such repository shall be subject to approval or disapproval by the Commission as part of the construction authorization process under subsections (b) through (d) of section 114.

TITLE TO MATERIAL

SEC. 123. Delivery, and acceptance by the Secretary, of any high-level radioactive waste or spent nuclear fuel for a repository constructed under this subtitle shall constitute a transfer to the Secretary of title to such waste or spent fuel. 42 USC 10143.

CONSIDERATION OF EFFECT OF ACQUISITION OF WATER RIGHTS

SEC. 124. The Secretary shall give full consideration to whether the development, construction, and operation of a repository may require any purchase or other acquisition of water rights that will have a significant adverse effect on the present or future development of the area in which such repository is located. The Secretary shall mitigate any such adverse effects to the maximum extent practicable. 42 USC 10144.

TERMINATION OF CERTAIN PROVISIONS

SEC. 125. Sections 119 and 120 shall cease to have effect at such time as a repository developed under this subtitle is licensed to receive and possess high-level radioactive waste and spent nuclear fuel. 42 USC 10145.

SUBTITLE B—INTERIM STORAGE PROGRAM

FINDINGS AND PURPOSES

SEC. 131. (a) FINDINGS.—The Congress finds that— 42 USC 10151.

(1) the persons owning and operating civilian nuclear power reactors have the primary responsibility for providing interim storage of spent nuclear fuel from such reactors, by maximizing, to the extent practical, the effective use of existing storage facilities at the site of each civilian nuclear power reactor, and by adding new onsite storage capacity in a timely manner where practical;

(2) the Federal Government has the responsibility to encourage and expedite the effective use of existing storage facilities and the addition of needed new storage capacity at the site of each civilian nuclear power reactor; and

(3) the Federal Government has the responsibility to provide, in accordance with the provisions of this subtitle, not more than 1,900 metric tons of capacity for interim storage of spent nuclear fuel for civilian nuclear power reactors that cannot reasonably provide adequate storage capacity at the sites of such

reactors when needed to assure the continued, orderly operation of such reactors.

(b) PURPOSES.—The purposes of this subtitle are—

(1) to provide for the utilization of available spent nuclear fuel pools at the site of each civilian nuclear power reactor to the extent practical and the addition of new spent nuclear fuel storage capacity where practical at the site of such reactor; and

(2) to provide, in accordance with the provisions of this subtitle, for the establishment of a federally owned and operated system for the interim storage of spent nuclear fuel at one or more facilities owned by the Federal Government with not more than 1,900 metric tons of capacity to prevent disruptions in the orderly operation of any civilian nuclear power reactor that cannot reasonably provide adequate spent nuclear fuel storage capacity at the site of such reactor when needed.

AVAILABLE CAPACITY FOR INTERIM STORAGE OF SPENT NUCLEAR FUEL

42 USC 10152.

SEC. 132. The Secretary, the Commission, and other authorized Federal officials shall each take such actions as such official considers necessary to encourage and expedite the effective use of available storage, and necessary additional storage, at the site of each civilian nuclear power reactor consistent with—

(1) the protection of the public health and safety, and the environment;

(2) economic considerations;

(3) continued operation of such reactor;

(4) any applicable provisions of law; and

(5) the views of the population surrounding such reactor.

INTERIM AT REACTOR STORAGE

Licensing procedures.
42 USC 10153.

SEC. 133. The Commission shall, by rule, establish procedures for the licensing of any technology approved by the Commission under section 219(a) for use at the site of any civilian nuclear power reactor. The establishment of such procedures shall not preclude the licensing, under any applicable procedures or rules of the Commission in effect prior to such establishment, of any technology for the storage of civilian spent nuclear fuel at the site of any civilian nuclear power reactor.

LICENSING OF FACILITY EXPANSIONS AND TRANSSHIPMENTS

42 USC 10154.

SEC. 134. (a) ORAL ARGUMENT.—In any Commission hearing under section 189 of the Atomic Energy Act of 1954 (42 U.S.C. 2239) on an application for a license, or for an amendment to an existing license, filed after the date of the enactment of this Act, to expand the spent nuclear fuel storage capacity at the site of a civilian nuclear power reactor, through the use of high-density fuel storage racks, fuel rod compaction, the transshipment of spent nuclear fuel to another civilian nuclear power reactor within the same utility system, the construction of additional spent nuclear fuel pool capacity or dry storage capacity, or by other means, the Commission shall, at the request of any party, provide an opportunity for oral argument with respect to any matter which the Commission determines to be in controversy among the parties. The oral argument shall be preceded by such discovery procedures as the rules of the Commission shall

Summary submittal of facts, data and arguments.

provide. The Commission shall require each party, including the Commission staff, to submit in written form, at the time of the oral argument, a summary of the facts, data, and arguments upon which such party proposes to rely that are known at such time to such party. Only facts and data in the form of sworn testimony or written submission may be relied upon by the parties during oral argument. Of the materials that may be submitted by the parties during oral argument, the Commission shall only consider those facts and data that are submitted in the form of sworn testimony or written submission.

(b) ADJUDICATORY HEARING.—(1) At the conclusion of any oral argument under subsection (a), the Commission shall designate any disputed question of fact, together with any remaining questions of law, for resolution in an adjudicatory hearing only if it determines that—

(A) there is a genuine and substantial dispute of fact which can only be resolved with sufficient accuracy by the introduction of evidence in an adjudicatory hearing; and

(B) the decision of the Commission is likely to depend in whole or in part on the resolution of such dispute.

(2) In making a determination under this subsection, the Commission—

(A) shall designate in writing the specific facts that are in genuine and substantial dispute, the reason why the decision of the agency is likely to depend on the resolution of such facts, and the reason why an adjudicatory hearing is likely to resolve the dispute; and

(B) shall not consider—

(i) any issue relating to the design, construction, or operation of any civilian nuclear power reactor already licensed to operate at such site, or any civilian nuclear power reactor for which a construction permit has been granted at such site, unless the Commission determines that any such issue substantially affects the design, construction, or operation of the facility or activity for which such license application, authorization, or amendment is being considered; or

(ii) any siting or design issue fully considered and decided by the Commission in connection with the issuance of a construction permit or operating license for a civilian nuclear power reactor at such site, unless (I) such issue results from any revision of siting or design criteria by the Commission following such decision; and (II) the Commission determines that such issue substantially affects the design, construction, or operation of the facility or activity for which such license application, authorization, or amendment is being considered.

(3) The provisions of paragraph (2)(B) shall apply only with respect to licenses, authorizations, or amendments to licenses or authorizations, applied for under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) before December 31, 2005.

(4) The provisions of this section shall not apply to the first application for a license or license amendment received by the Commission to expand onsite spent fuel storage capacity by the use of a new technology not previously approved for use at any nuclear powerplant by the Commission.

(c) JUDICIAL REVIEW.—No court shall hold unlawful or set aside a decision of the Commission in any proceeding described in subsection (a) because of a failure by the Commission to use a particular procedure pursuant to this section unless—

(1) an objection to the procedure used was presented to the Commission in a timely fashion or there are extraordinary circumstances that excuse the failure to present a timely objection; and

(2) the court finds that such failure has precluded a fair consideration and informed resolution of a significant issue of the proceeding taken as a whole.

STORAGE OF SPENT NUCLEAR FUEL

Ante, p. 2205.
42 USC 10155.

SEC. 135. (a) STORAGE CAPACITY.—(1) Subject to section 8, the Secretary shall provide, in accordance with paragraph (5), not more than 1,900 metric tons of capacity for the storage of spent nuclear fuel from civilian nuclear power reactors. Such storage capacity shall be provided through any one or more of the following methods, used in any combination determined by the Secretary to be appropriate:

(A) use of available capacity at one or more facilities owned by the Federal Government on the date of the enactment of this Act, including the modification and expansion of any such facilities, if the Commission determines that such use will adequately protect the public health and safety, except that such use shall not—

(i) render such facilities subject to licensing under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) or the Energy Reorganization Act of 1974 (42 U.S.C. 5801 et seq.); or

(ii) except as provided in subsection (c) require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)), such facility is already being used, or has previously been used, for such storage or for any similar purpose.

(B) acquisition of any modular or mobile spent nuclear fuel storage equipment, including spent nuclear fuel storage casks, and provision of such equipment, to any person generating or holding title to spent nuclear fuel, at the site of any civilian nuclear power reactor operated by such person or at any site owned by the Federal Government on the date of enactment of this Act;

(C) construction of storage capacity at any site of a civilian nuclear power reactor.

(2) Storage capacity authorized by paragraph (1) shall not be provided at any Federal or non-Federal site within which there is a candidate site for a repository. The restriction in the preceding sentence shall only apply until such time as the Secretary decides that such candidate site is no longer a candidate site under consideration for development as a repository.

(3) In selecting methods of providing storage capacity under paragraph (1), the Secretary shall consider the timeliness of the availability of each such method and shall seek to minimize the transportation of spent nuclear fuel, the public health and safety impacts, and the costs of providing such storage capacity.

(4) In providing storage capacity through any method described in paragraph (1), the Secretary shall comply with any applicable requirements for licensing or authorization of such method, except as provided in paragraph (1)(A)(i).

(5) The Secretary shall ensure that storage capacity is made available under paragraph (1) when needed, as determined on the basis of the storage needs specified in contracts entered into under section 136(a), and shall accept upon request any spent nuclear fuel as covered under such contracts.

(6) For purposes of paragraph (1)(A), the term "facility" means any building or structure.

"Facility."

(b) CONTRACTS.—(1) Subject to the capacity limitation established in subsections (a) (1) and (d), the Secretary shall offer to enter into, and may enter into, contracts under section 136(a) with any person generating or owning spent nuclear fuel for purposes of providing storage capacity for such spent fuel under this section only if the Commission determines that—

(A) adequate storage capacity to ensure the continued orderly operation of the civilian nuclear power reactor at which such spent nuclear fuel is generated cannot reasonably be provided by the person owning and operating such reactor at such site, or at the site of any other civilian nuclear power reactor operated by such person, and such capacity cannot be made available in a timely manner through any method described in subparagraph (B); and

(B) such person is diligently pursuing licensed alternatives to the use of Federal storage capacity for the storage of spent nuclear fuel expected to be generated by such person in the future, including—

(i) expansion of storage facilities at the site of any civilian nuclear power reactor operated by such person;

(ii) construction of new or additional storage facilities at the site of any civilian nuclear power reactor operated by such person;

(iii) acquisition of modular or mobile spent nuclear fuel storage equipment, including spent nuclear fuel storage casks, for use at the site of any civilian nuclear power reactor operated by such person; and

(iv) transshipment to another civilian nuclear power reactor owned by such person.

(2) In making the determination described in paragraph (1)(A), the Commission shall ensure maintenance of a full core reserve storage capability at the site of the civilian nuclear power reactor involved unless the Commission determines that maintenance of such capability is not necessary for the continued orderly operation of such reactor.

(3) The Commission shall complete the determinations required in paragraph (1) with respect to any request for storage capacity not later than 6 months after receipt of such request by the Commission.

(c) ENVIRONMENTAL REVIEW.—(1) The provision of 300 or more metric tons of storage capacity at any one Federal site under subsection (a)(1)(A) shall be considered to be a major Federal action requiring preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)).

(2)(A) The Secretary shall prepare, and make available to the public, an environmental assessment of the probable impacts of any

Public availability.

provision of less than 300 metric tons of storage capacity at any one Federal site under subsection (a)(1)(A) that requires the modification or expansion of any facility at the site, and a discussion of alternative activities that may be undertaken to avoid such impacts. Such environmental assessment shall include—

Environmental assessment.

(i) an estimate of the amount of storage capacity to be made available at such site;

(ii) an evaluation as to whether the facilities to be used at such site are suitable for the provision of such storage capacity;

(iii) a description of activities planned by the Secretary with respect to the modification or expansion of the facilities to be used at such site;

(iv) an evaluation of the effects of the provision of such storage capacity at such site on the public health and safety, and the environment;

(v) a reasonable comparative evaluation of current information with respect to such site and facilities and other sites and facilities available for the provision of such storage capacity;

(vi) a description of any other sites and facilities that have been considered by the Secretary for the provision of such storage capacity; and

(vii) an assessment of the regional and local impacts of providing such storage capacity at such site, including the impacts on transportation.

Judicial review.

(B) The issuance of any environmental assessment under this paragraph shall be considered to be a final agency action subject to judicial review in accordance with the provisions of chapter 7 of title 5, United States Code. Such judicial review shall be limited to the sufficiency of such assessment with respect to the items described in clauses (i) through (vii) of subparagraph (A).

5 USC 701 *et seq.*

(3) Judicial review of any environmental impact statement or environmental assessment prepared pursuant to this subsection shall be conducted in accordance with the provisions of section 119.

(d) REVIEW OF SITES AND STATE PARTICIPATION.—(1) In carrying out the provisions of this subtitle with regard to any interim storage of spent fuel from civilian nuclear power reactors which the Secretary is authorized by section 135 to provide, the Secretary shall, as soon as practicable, notify, in writing, the Governor and the State legislature of any State and the Tribal Council of any affected Indian tribe in such State in which is located a potentially acceptable site or facility for such interim storage of spent fuel of his intention to investigate that site or facility.

Investigation.

(2) During the course of investigation of such site or facility, the Secretary shall keep the Governor, State legislature, and affected Tribal Council currently informed of the progress of the work, and results of the investigation. At the time of selection by the Secretary of any site or existing facility, but prior to undertaking any site-specific work or alterations, the Secretary shall promptly notify the Governor, the legislature, and any affected Tribal Council in writing of such selection, and subject to the provisions of paragraph (6) of this subsection, shall promptly enter into negotiations with such State and affected Tribal Council to establish a cooperative agreement under which such State and Council shall have the right to participate in a process of consultation and cooperation, based on public health and safety and environmental concerns, in all stages of the planning, development, modification, expansion, operation, and closure of storage capacity at a site or facility within such State

for the interim storage of spent fuel from civilian nuclear power reactors. Public participation in the negotiation of such an agreement shall be provided for and encouraged by the Secretary, the State, and the affected Tribal Council. The Secretary, in cooperation with the States and Indian tribes, shall develop and publish minimum guidelines for public participation in such negotiations, but the adequacy of such guidelines or any failure to comply with such guidelines shall not be a basis for judicial review.

Guidelines.

Cooperative agreement.

(3) The cooperative agreement shall include, but need not be limited to, the sharing in accordance with applicable law of all technical and licensing information, the utilization of available expertise, the facilitating of permitting procedures, joint project review, and the formulation of joint surveillance and monitoring arrangements to carry out applicable Federal and State laws. The cooperative agreement also shall include a detailed plan or schedule of milestones, decision points and opportunities for State or eligible Tribal Council review and objection. Such cooperative agreement shall provide procedures for negotiating and resolving objections of the State and affected Tribal Council in any stage of planning, development, modification, expansion, operation, or closure of storage capacity at a site or facility within such State. The terms of any cooperative agreement shall not affect the authority of the Nuclear Regulatory Commission under existing law.

"Process of consultation and cooperation."

(4) For the purpose of this subsection, "process of consultation and cooperation" means a methodology by which the Secretary (A) keeps the State and eligible Tribal Council fully and currently informed about the aspects of the project related to any potential impact on the public health and safety and environment; (B) solicits, receives, and evaluates concerns and objections of such State and Council with regard to such aspects of the project on an ongoing basis; and (C) works diligently and cooperatively to resolve, through arbitration or other appropriate mechanisms, such concerns and objections. The process of consultation and cooperation shall not include the grant of a right to any State or Tribal Council to exercise an absolute veto of any aspect of the planning, development, modification, expansion, or operation of the project.

(5) The Secretary and the State and affected Tribal Council shall seek to conclude the agreement required by paragraph (2) as soon as practicable, but not later than 180 days following the date of notification of the selection under paragraph (2). The Secretary shall periodically report to the Congress thereafter on the status of the agreements approved under paragraph (3). Any report to the Congress on the status of negotiations of such agreement by the Secretary shall be accompanied by comments solicited by the Secretary from the State and eligible Tribal Council.

Report to Congress.

(6)(A) Upon deciding to provide an aggregate of 300 or more metric tons of storage capacity under subsection (a)(1) at any one site, the Secretary shall notify the Governor and legislature of the State where such site is located, or the governing body of the Indian tribe in whose reservation such site is located, as the case may be, of such decision. During the 60-day period following receipt of notification by the Secretary of his decision to provide an aggregate of 300 or more metric tons of storage capacity at any one site, the Governor or legislature of the State in which such site is located, or the governing body of the affected Indian tribe where such site is located, as the case may be, may disapprove the provision of 300 or more metric tons of storage capacity at the site involved and submit to the

Notice of disapproval, submittal to Congress.

Congress a notice of such disapproval. A notice of disapproval shall be considered to be submitted to the Congress on the date of the transmittal of such notice of disapproval to the Speaker of the House and the President pro tempore of the Senate. Such notice of disapproval shall be accompanied by a statement of reasons explaining why the provision of such storage capacity at such site was disapproved by such Governor or legislature or the governing body of such Indian tribe.

(B) Unless otherwise provided by State law, the Governor or legislature of each State shall have authority to submit a notice of disapproval to the Congress under subparagraph (A). In any case in which State law provides for submission of any such notice of disapproval by any other person or entity, any reference in this subtitle to the Governor or legislature of such State shall be considered to refer instead to such other person or entity.

(C) The authority of the Governor and legislature of each State under this paragraph shall not be applicable with respect to any site located on a reservation.

Ante, p. 2217.

"Resolution."

(D) If any notice of disapproval is submitted to the Congress under subparagraph (A), the proposed provision of 300 or more metric tons of storage capacity at the site involved shall be disapproved unless, during the first period of 90 calendar days of continuous session of the Congress following the date of the receipt by the Congress of such notice of disapproval, the Congress passes a resolution approving such proposed provision of storage capacity in accordance with the procedures established in this paragraph and subsections (d) through (f) of section 115 and such resolution thereafter becomes law. For purposes of this paragraph, the term "resolution" means a joint resolution of either House of the Congress, the matter after the resolving clause of which is as follows: "That there hereby is approved the provision of 300 or more metric tons of spent nuclear fuel storage capacity at the site located at ______________, with respect to which a notice of disapproval was submitted by ______________ on ______________.". The first blank space in such resolution shall be filled with the geographic location of the site involved; the second blank space in such resolution shall be filled with the designation of the State Governor and legislature or affected Indian tribe governing body submitting the notice of disapproval involved; and the last blank space in such resolution shall be filled with the date of submission of such notice of disapproval.

(E) For purposes of the consideration of any resolution described in subparagraph (D), each reference in subsections (d) and (e) of section 115 to a resolution of repository siting approval shall be considered to refer to the resolution described in such subparagraph.

"Affected Tribal Council."

(7) As used in this section, the term "affected Tribal Council" means the governing body of any Indian tribe within whose reservation boundaries there is located a potentially acceptable site for interim storage capacity of spent nuclear fuel from civilian nuclear power reactors, or within whose boundaries a site for such capacity is selected by the Secretary, or whose federally defined possessory or usage rights to other lands outside of the reservation's boundaries arising out of congressionally ratified treaties, as determined by the Secretary of the Interior pursuant to a petition filed with him by the appropriate governmental officials of such tribe, may be substantially and adversely affected by the establishment of any such storage capacity.

(e) LIMITATIONS.—Any spent nuclear fuel stored under this section shall be removed from the storage site or facility involved as soon as practicable, but in any event not later than 3 years following the date on which a repository or monitored retrievable storage facility developed under this Act is available for disposal of such spent nuclear fuel.

(f) REPORT.—The Secretary shall annually prepare and submit to the Congress a report on any plans of the Secretary for providing storage capacity under this section. Such report shall include a description of the specific manner of providing such storage selected by the Secretary, if any. The Secretary shall prepare and submit the first such report not later than 1 year after the date of the enactment of this Act.

(g) CRITERIA FOR DETERMINING ADEQUACY OF AVAILABLE STORAGE CAPACITY.—Not later than 90 days after the date of the enactment of this Act, the Commission pursuant to section 553 of the Administrative Procedures Act, shall propose, by rule, procedures and criteria for making the determination required by subsection (b) that a person owning and operating a civilian nuclear power reactor cannot reasonably provide adequate spent nuclear fuel storage capacity at the civilian nuclear power reactor site when needed to ensure the continued orderly operation of such reactor. Such criteria shall ensure the maintenance of a full core reserve storage capability at the site of such reactor unless the Commission determines that maintenance of such capability is not necessary for the continued orderly operation of such reactor. Such criteria shall identify the feasibility of reasonably providing such adequate spent nuclear fuel storage capacity, taking into account economic, technical, regulatory, and public health and safety factors, through the use of high-density fuel storage racks, fuel rod compaction, transshipment of spent nuclear fuel to another civilian nuclear power reactor within the same utility system, construction of additional spent nuclear fuel pool capacity, or such other technologies as may be approved by the Commission. 5 USC 553.

(h) APPLICATION.—Notwithstanding any other provision of law, nothing in this Act shall be construed to encourage, authorize, or require the private or Federal use, purchase, lease, or other acquisition of any storage facility located away from the site of any civilian nuclear power reactor and not owned by the Federal Government on the date of the enactment of this Act.

(i) COORDINATION WITH RESEARCH AND DEVELOPMENT PROGRAM.—To the extent available, and consistent with the provisions of this section, the Secretary shall provide spent nuclear fuel for the research and development program authorized in section 217 from spent nuclear fuel received by the Secretary for storage under this section. Such spent nuclear fuel shall not be subject to the provisions of subsection (e).

INTERIM STORAGE FUND

SEC. 136. (a) CONTRACTS.—(1) During the period following the date of the enactment of this Act, but not later than January 1, 1990, the Secretary is authorized to enter into contracts with persons who generate or own spent nuclear fuel resulting from civilian nuclear activities for the storage of such spent nuclear fuel in any storage capacity provided under this subtitle: *Provided, however,* That the Secretary shall not enter into contracts for spent nuclear fuel in 42 USC 10156.

amounts in excess of the available storage capacity specified in section 135(a). Those contracts shall provide that the Federal Government will (1) take title at the civilian nuclear power reactor site, to such amounts of spent nuclear fuel from the civilian nuclear power reactor as the Commission determines cannot be stored onsite, (2) transport the spent nuclear fuel to a federally owned and operated interim away-from-reactor storage facility, and (3) store such fuel in the facility pending further processing, storage, or disposal. Each such contract shall (A) provide for payment to the Secretary of fees determined in accordance with the provisions of this section; and (B) specify the amount of storage capacity to be provided for the person involved.

Study; report to Congress.

(2) The Secretary shall undertake a study and, not later than 180 days after the date of the enactment of this Act, submit to the Congress a report, establishing payment charges that shall be calculated on an annual basis, commencing on or before January 1, 1984. Such payment charges and the calculation thereof shall be published in the Federal Register, and shall become effective not less than 30 days after publication. Each payment charge published in the Federal Register under this paragraph shall remain effective for a period of 12 months from the effective date as the charge for the cost of the interim storage of any spent nuclear fuel. The report of the Secretary shall specify the method and manner of collection (including the rates and manner of payment) and any legislative recommendations determined by the Secretary to be appropriate.

Publication in Federal Register.

Fees.

(3) Fees for storage under this subtitle shall be established on a nondiscriminatory basis. The fees to be paid by each person entering into a contract with the Secretary under this subsection shall be based upon an estimate of the pro rata costs of storage and related activities under this subtitle with respect to such person, including the acquisition, construction, operation, and maintenance of any facilities under this subtitle.

(4) The Secretary shall establish in writing criteria setting forth the terms and conditions under which such storage services shall be made available.

(5) Except as provided in section 137, nothing in this or any other Act requires the Secretary, in carrying out the responsibilities of this section, to obtain a license or permit to possess or own spent nuclear fuel.

(b) LIMITATION.—No spent nuclear fuel generated or owned by any department of the United States referred to in section 101 or 102 of title 5, United States Code, may be stored by the Secretary in any storage capacity provided under this subtitle unless such department transfers to the Secretary, for deposit in the Interim Storage Fund, amounts equivalent to the fees that would be paid to the Secretary under the contracts referred to in this section if such spent nuclear fuel were generated by any other person.

(c) ESTABLISHMENT OF INTERIM STORAGE FUND.—There hereby is established in the Treasury of the United States a separate fund, to be known as the Interim Storage Fund. The Storage Fund shall consist of—

(1) all receipts, proceeds, and recoveries realized by the Secretary under subsections (a), (b), and (e), which shall be deposited in the Storage Fund immediately upon their realization;

(2) any appropriations made by the Congress to the Storage Fund; and

(3) any unexpended balances available on the date of the enactment of this Act for functions or activities necessary or incident to the interim storage of civilian spent nuclear fuel, which shall automatically be transferred to the Storage Fund on such date.

(d) USE OF STORAGE FUND.—The Secretary may make expenditures from the Storage Fund, subject to subsection (e), for any purpose necessary or appropriate to the conduct of the functions and activities of the Secretary, or the provision or anticipated provision of services, under this subtitle, including—

(1) the identification, development, licensing, construction, operation, decommissioning, and post-decommissioning maintenance and monitoring of any interim storage facility provided under this subtitle;

(2) the administrative cost of the interim storage program;

(3) the costs associated with acquisition, design, modification, replacement, operation, and construction of facilities at an interim storage site, consistent with the restrictions in section 135;

(4) the cost of transportation of spent nuclear fuel; and

(5) impact assistance as described in subsection (e).

Payments.

(e) IMPACT ASSISTANCE.—(1) Beginning the first fiscal year which commences after the date of the enactment of this Act, the Secretary shall make annual impact assistance payments to a State or appropriate unit of local government, or both, in order to mitigate social or economic impacts occasioned by the establishment and subsequent operation of any interim storage capacity within the jurisdicational boundaries of such government or governments and authorized under this subtitle: *Provided, however,* That such impact assistance payments shall not exceed (A) ten per centum of the costs incurred in paragraphs (1) and (2), or (B) $15 per kilogram of spent fuel, whichever is less;

(2) Payments made available to States and units of local government pursuant to this section shall be—

(A) allocated in a fair and equitable manner with a priority to those States or units of local government suffering the most severe impacts; and

(B) utilized by States or units of local governments only for (i) planning, (ii) construction and maintenance of public services, (iii) provision of public services related to the providing of such interim storage authorized under this title, and (iv) compensation for loss of taxable property equivalent to that if the storage had been provided under private ownership.

Regulations.

(3) Such payments shall be subject to such terms and conditions as the Secretary determines necessary to ensure that the purposes of this subsection shall be achieved. The Secretary shall issue such regulations as may be necessary to carry out the provisions of this subsection.

(4) Payments under this subsection shall be made available solely from the fees determined under subsection (a).

(5) The Secretary is authorized to consult with States and appropriate units of local government in advance of commencement of establishment of storage capacity authorized under this subtitle in an effort to determine the level of the payment such government would be eligible to receive pursuant to this subsection.

"Unit of local government."

(6) As used in this subsection, the term "unit of local government" means a county, parish, township, municipality, and shall include a

borough existing in the State of Alaska on the date of the enactment of this subsection, and any other unit of government below the State level which is a unit of general government as determined by the Secretary.

Report to Congress.

(f) ADMINISTRATION OF STORAGE FUND.—(1) The Secretary of the Treasury shall hold the Storage Fund and, after consultation with the Secretary, annually report to the Congress on the financial condition and operations of the Storage Fund during the preceding fiscal year.

Budget submittal.

Ante, p. 907.

(2) The Secretary shall submit the budget of the Storage Fund to the Office of Management and Budget triennially along with the budget of the Department of Energy submitted at such time in accordance with chapter 11 of title 31, United States Code. The budget of the Storage Fund shall consist of estimates made by the Secretary of expenditures from the Storage Fund and other relevant financial matters for the succeeding 3 fiscal years, and shall be included in the Budget of the United States Government. The Secretary may make expenditures from the Storage Fund, subject to appropriations which shall remain available until expended. Appropriations shall be subject to triennial authorization.

(3) If the Secretary determines that the Storage Fund contains at any time amounts in excess of current needs, the Secretary may request the Secretary of the Treasury to invest such amounts, or any portion of such amounts as the Secretary determines to be appropriate, in obligations of the United States—

(A) having maturities determined by the Secretary of the Treasury to be appropriate to the needs of the Storage Fund; and

(B) bearing interest at rates determined to be appropriate by the Secretary of the Treasury, taking into consideration the current average market yield on outstanding marketable obligations of the United States with remaining periods to maturity comparable to the maturities of such investments, except that the interest rate on such investments shall not exceed the average interest rate applicable to existing borrowings.

Ante, p. 927.

(4) Receipts, proceeds, and recoveries realized by the Secretary under this section, and expenditures of amounts from the Storage Fund, shall be exempt from annual apportionment under the provisions of subchapter II of chapter 15 of title 31, United States Code.

(5) If at any time the moneys available in the Storage Fund are insufficient to enable the Secretary to discharge his responsibilities under this subtitle, the Secretary shall issue to the Secretary of the Treasury obligations in such forms and denominations, bearing such maturities, and subject to such terms and conditions as may be agreed to by the Secretary and the Secretary of the Treasury. The total of such obligations shall not exceed amounts provided in appropriation Acts. Redemption of such obligations shall be made by the Secretary from moneys available in the Storage Fund. Such obligations shall bear interest at a rate determined by the Secretary of the Treasury, which shall be not less than a rate determined by taking into consideration the average market yield on outstanding marketable obligations of the United States of comparable maturities during the month preceding the issuance of the obligations under this paragraph. The Secretary of the Treasury shall purchase any issued obligations, and for such purpose the Secretary of the Treasury is authorized to use as a public debt transaction the proceeds from the sale of any securities issued under chapter 31 of

Ante, p. 937.

title 31, United States Code, and the purposes for which securities may be issued under such Act are extended to include any purchase of such obligations. The Secretary of the Treasury may at any time sell any of the obligations acquired by him under this paragraph. All redemptions, purchases, and sales by the Secretary of the Treasury of obligations under this paragraph shall be treated as public debt transactions of the United States.

Interest payments.

(6) Any appropriations made available to the Storage Fund for any purpose described in subsection (d) shall be repaid into the general fund of the Treasury, together with interest from the date of availability of the appropriations until the date of repayment. Such interest shall be paid on the cumulative amount of appropriations available to the Storage Fund, less the average undisbursed cash balance in the Storage Fund account during the fiscal year involved. The rate of such interest shall be determined by the Secretary of the Treasury taking into consideration the average market yield during the month preceding each fiscal year on outstanding marketable obligations of the United States of comparable maturity. Interest payments may be deferred with the approval of the Secretary of the Treasury, but any interest payments so deferred shall themselves bear interest.

Deferral.

42 USC 10157.

SEC. 137. (a) TRANSPORTATION.—(1) Transportation of spent nuclear fuel under section 136(a) shall be subject to licensing and regulation by the Commission and by the Secretary of Transportation as provided for transportation of commercial spent nuclear fuel under existing law.

(2) The Secretary, in providing for the transportation of spent nuclear fuel under this Act, shall utilize by contract private industry to the fullest extent possible in each aspect of such transportation. The Secretary shall use direct Federal services for such transportation only upon a determination of the Secretary of Transportation, in consultation with the Secretary, that private industry is unable or unwilling to provide such transportation services at reasonable cost.

SUBTITLE C—MONITORED RETRIEVABLE STORAGE

MONITORED RETRIEVABLE STORAGE

42 USC 10161.

SEC. 141. (a) FINDINGS.—The Congress finds that—

(1) long-term storage of high-level radioactive waste or spent nuclear fuel in monitored retrievable storage facilities is an option for providing safe and reliable management of such waste or spent fuel;

(2) the executive branch and the Congress should proceed as expeditiously as possible to consider fully a proposal for construction of one or more monitored retrievable storage facilities to provide such long-term storage;

(3) the Federal Government has the responsibility to ensure that site-specific designs for such facilities are available as provided in this section;

(4) the generators and owners of the high-level radioactive waste and spent nuclear fuel to be stored in such facilities have the responsibility to pay the costs of the long-term storage of such waste and spent fuel; and

(5) disposal of high-level radioactive waste and spent nuclear fuel in a repository developed under this Act should proceed

regardless of any construction of a monitored retrievable storage facility pursuant to this section.

(b) Submission of Proposal by Secretary.—(1) On or before June 1, 1985, the Secretary shall complete a detailed study of the need for and feasibility of, and shall submit to the Congress a proposal for, the construction of one or more monitored retrievable storage facilities for high-level radioactive waste and spent nuclear fuel. Each such facility shall be designed—

(A) to accommodate spent nuclear fuel and high-level radioactive waste resulting from civilian nuclear activities;

(B) to permit continuous monitoring, management, and maintenance of such spent fuel and waste for the foreseeable future;

(C) to provide for the ready retrieval of such spent fuel and waste for further processing or disposal; and

(D) to safely store such spent fuel and waste as long as may be necessary by maintaining such facility through appropriate means, including any required replacement of such facility.

(2) Such proposal shall include—

(A) the establishment of a Federal program for the siting, development, construction, and operation of facilities capable of safely storing high-level radioactive waste and spent nuclear fuel, which facilities are to be licensed by the Commission;

(B) a plan for the funding of the construction and operation of such facilities, which plan shall provide that the costs of such activities shall be borne by the generators and owners of the high-level radioactive waste and spent nuclear fuel to be stored in such facilities;

(C) site-specific designs, specifications, and cost estimates sufficient to (i) solicit bids for the construction of the first such facility; (ii) support congressional authorization of the construction of such facility; and (iii) enable completion and operation of such facility as soon as practicable following congressional authorization of such facility; and

(D) a plan for integrating facilities constructed pursuant to this section with other storage and disposal facilities authorized in this Act.

Consultations.

(3) In formulating such proposal, the Secretary shall consult with the Commission and the Administrator, and shall submit their comments on such proposal to the Congress at the time such proposal is submitted.

(4) The proposal shall include, for the first such facility, at least 3 alternative sites and at least 5 alternative combinations of such proposed sites and facility designs consistent with the criteria of paragraph (b)(1). The Secretary shall recommend the combination among the alternatives that the Secretary deems preferable. The environmental assessment under subsection (c) shall include a full analysis of the relative advantages and disadvantages of all 5 such alternative combinations of proposed sites and proposed facility designs.

(c) Environmental Impact Statements.—(1) Preparation and submission to the Congress of the proposal required in this section shall not require the preparation of an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)). The Secretary shall prepare, in accordance with regulations issued by the Secretary implementing such Act, an environmental assessment with respect to such proposal. Such environmental assessment shall be based upon available

Environmental assessment.

Submittal to Congress.

information regarding alternative technologies for the storage of spent nuclear fuel and high-level radioactive waste. The Secretary shall submit such environmental assessment to the Congress at the time such proposal is submitted.

(2) If the Congress by law, after review of the proposal submitted by the Secretary under subsection (b), specifically authorizes construction of a monitored retrievable storage facility, the requirements of the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) shall apply with respect to construction of such facility, except that any environmental impact statement prepared with respect to such facility shall not be required to consider the need for such facility or any alternative to the design criteria for such facility set forth in subsection (b)(1).

(d) Licensing.—Any facility authorized pursuant to this section shall be subject to licensing under section 202(3) of the Energy Reorganization Act of 1974 (42 U.S.C. 5842(3)). In reviewing the application filed by the Secretary for licensing of the first such facility, the Commission may not consider the need for such facility or any alternative to the design criteria for such facility set forth in subsection (b)(1).

(e) Clarification.—Nothing in this section limits the consideration of alternative facility designs consistent with the criteria of paragraph (b)(1) in any environmental impact statement, or in any licensing procedure of the Commission, with respect to any monitored, retrievable facility authorized pursuant to this section.

Payments.

(f) Impact Assistance.—(1) Upon receipt by the Secretary of congressional authorization to construct a facility described in subsection (b), the Secretary shall commence making annual impact aid payments to appropriate units of general local government in order to mitigate any social or economic impacts resulting from the construction and subsequent operation of any such facility within the jurisdictional boundaries of any such unit.

(2) Payments made available to units of general local government under this subsection shall be—

(A) allocated in a fair and equitable manner, with priority given to units of general local government determined by the Secretary to be most severely affected; and

(B) utilized by units of general local government only for planning, construction, maintenance, and provision of public services related to the siting of such facility.

Regulations.

(3) Such payments shall be subject to such terms and conditions as the Secretary determines are necessary to ensure achievement of the purposes of this subsection. The Secretary shall issue such regulations as may be necessary to carry out the provisions of this subsection.

(4) Such payments shall be made available entirely from funds held in the Nuclear Waste Fund established in section 302(c) and shall be available only to the extent provided in advance in appropriation Acts.

Consultations.

(5) The Secretary may consult with appropriate units of general local government in advance of commencement of construction of any such facility in an effort to determine the level of payments each such unit is eligible to receive under this subsection.

Ante, p. 2208.

(g) Limitation.—No monitored retrievable storage facility developed pursuant to this section may be constructed in any State in which there is located any site approved for site characterization under section 112. The restriction in the preceding sentence shall only apply until such time as the Secretary decides that such candidate site is no longer a candidate site under consideration for development as a repository. Such restriction shall continue to apply to any site selected for construction as a repository.

Ante, pp. 2217, 2220, 2222, 2225.

(h) PARTICIPATION OF STATES AND INDIAN TRIBES.—Any facility authorized pursuant to this section shall be subject to the provisions of sections 115, 116(a), 116(b), 116(d), 117, and 118. For purposes of carrying out the provisions of this subsection, any reference in sections 115 through 118 to a repository shall be considered to refer to a monitored retrievable storage facility.

SUBTITLE D—LOW-LEVEL RADIOACTIVE WASTE

FINANCIAL ARRANGEMENTS FOR LOW-LEVEL RADIOACTIVE WASTE SITE CLOSURE

42 USC 10171.

SEC. 151. (a) FINANCIAL ARRANGEMENTS.—(1) The Commission shall establish by rule, regulation, or order, after public notice, and in accordance with section 181 of the Atomic Energy Act of 1954 (42 U.S.C. 2231), such standards and instructions as the Commission may deem necessary or desirable to ensure in the case of each license for the disposal of low-level radioactive waste that an adequate bond, surety, or other financial arrangement (as determined by the Commission) will be provided by a licensee to permit completion of all requirements established by the Commission for the decontamination, decommissioning, site closure, and reclamation of sites, structures, and equipment used in conjunction with such low-level radioactive waste. Such financial arrangements shall be provided and approved by the Commission, or, in the case of sites within the boundaries of any agreement State under section 274 of the Atomic Energy Act of 1954 (42 U.S.C. 2021), by the appropriate State or State entity, prior to issuance of licenses for low-level radioactive waste disposal or, in the case of licenses in effect on the date of the enactment of this Act, prior to termination of such licenses.

(2) If the Commission determines that any long-term maintenance or monitoring, or both, will be necessary at a site described in paragraph (1), the Commission shall ensure before termination of the license involved that the licensee has made available such bonding, surety, or other financial arrangements as may be necessary to ensure that any necessary long-term maintenance or monitoring needed for such site will be carried out by the person having title and custody for such site following license termination.

(b) TITLE AND CUSTODY.—(1) The Secretary shall have authority to assume title and custody of low-level radioactive waste and the land on which such waste is disposed of, upon request of the owner of such waste and land and following termination of the license issued by the Commission for such disposal, if the Commission determines that—

(A) the requirements of the Commission for site closure, decommissioning, and decontamination have been met by the licensee involved and that such licensee is in compliance with the provisions of subsection (a);

(B) such title and custody will be transferred to the Secretary without cost to the Federal Government; and

(C) Federal ownership and management of such site is necessary or desirable in order to protect the public health and safety, and the environment.

(2) If the Secretary assumes title and custody of any such waste and land under this subsection, the Secretary shall maintain such waste and land in a manner that will protect the public health and safety, and the environment.

(c) SPECIAL SITES.—If the low-level radioactive waste involved is the result of a licensed activity to recover zirconium, hafnium, and rare earths from source material, the Secretary, upon request of the owner of the site involved, shall assume title and custody of such waste and the land on which it is disposed when such site has been decontaminated and stabilized in accordance with the requirements established by the Commission and when such owner has made adequate financial arrangements approved by the Commission for the long-term maintenance and monitoring of such site.

TITLE II—RESEARCH, DEVELOPMENT, AND DEMONSTRATION REGARDING DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

PURPOSE

SEC. 211. It is the purpose of this title— 42 USC 10191.

(1) to provide direction to the Secretary with respect to the disposal of high-level radioactive waste and spent nuclear fuel;

(2) to authorize the Secretary, pursuant to this title—

(A) to provide for the construction, operation, and maintenance of a deep geologic test and evaluation facility; and

(B) to provide for a focused and integrated high-level radioactive waste and spent nuclear fuel research and development program, including the development of a test and evaluation facility to carry out research and provide an integrated demonstration of the technology for deep geologic disposal of high-level radioactive waste, and the development of the facilities to demonstrate dry storage of spent nuclear fuel; and

(3) to provide for an improved cooperative role between the Federal Government and States, affected Indian tribes, and units of general local government in the siting of a test and evaluation facility.

APPLICABILITY

SEC. 212. The provisions of this title are subject to section 8 and shall not apply to facilities that are used for the disposal of high-level radioactive waste, low-level radioactive waste, transuranic waste, or spent nuclear fuel resulting from atomic energy defense activities. *Ante*, p. 2205. 42 USC 10192.

IDENTIFICATION OF SITES

SEC. 213. (a) GUIDELINES.—Not later than 6 months after the date of the enactment of this Act and notwithstanding the failure of other agencies to promulgate standards pursuant to applicable law, the Secretary, in consultation with the Commission, the Director of the Geological Survey, the Administrator, the Council on Environ- 42 USC 10193.

mental Quality, and such other Federal agencies as the Secretary considers appropriate, is authorized to issue, pursuant to section 553 of title 5, United States Code, general guidelines for the selection of a site for a test and evaluation facility. Under such guidelines the Secretary shall specify factors that qualify or disqualify a site for development as a test and evaluation facility, including factors pertaining to the location of valuable natural resources, hydrogeophysics, seismic activity, and atomic energy defense activities, proximity to water supplies, proximity to populations, the effect upon the rights of users of water, and proximity to components of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Lands. Such guidelines shall require the Secretary to consider the various geologic media in which the site for a test and evaluation facility may be located and, to the extent practicable, to identify sites in different geologic media. The Secretary shall use guidelines established under this subsection in considering and selecting sites under this title.

(b) SITE IDENTIFICATION BY THE SECRETARY.—(1) Not later than 1 year after the date of the enactment of this Act, and following promulgation of guidelines under subsection (a), the Secretary is authorized to identify 3 or more sites, at least 2 of which shall be in different geologic media in the continental United States, and at least 1 of which shall be in media other than salt. Subject to Commission requirements, the Secretary shall give preference to sites for the test and evaluation facility in media possessing geochemical characteristics that retard aqueous transport of radionuclides. In order to provide a greater possible protection of public health and safety as operating experience is gained at the test and evaluation facility, and with the exception of the primary areas under review by the Secretary on the date of the enactment of this Act for the location of a test and evaluation facility or repository, all sites identified under this subsection shall be more than 15 statute miles from towns having a population of greater than 1,000 persons as determined by the most recent census unless such sites contain high-level radioactive waste prior to identification under this title. Each identification of a site shall be supported by an environmental assessment, which shall include a detailed statement of the basis for such identification and of the probable impacts of the siting research activities planned for such site, and a discussion of alternative activities relating to siting research that may be undertaken to avoid such impacts. Such environmental assessment shall include—

Environmental assessment.

(A) an evaluation by the Secretary as to whether such site is suitable for siting research under the guidelines established under subsection (a);

(B) an evaluation by the Secretary of the effects of the siting research activities at such site on the public health and safety and the environment;

(C) a reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered;

(D) a description of the decision process by which such site was recommended; and

(E) an assessment of the regional and local impacts of locating the proposed test and evaluation facility at such site.

(2) When the Secretary identifies a site, the Secretary shall as soon as possible notify the Governor of the State in which such site

is located, or the governing body of the affected Indian tribe where such site is located, of such identification and the basis of such identification. Additional sites for the location of the test and evaluation facility authorized in section 302(d) may be identified after such 1 year period, following the same procedure as if such sites had been identified within such period.

SITING RESEARCH AND RELATED ACTIVITIES

42 USC 10194.

SEC. 214. (a) IN GENERAL.—Not later than 30 months after the date on which the Secretary completes the identification of sites under section 213, the Secretary is authorized to complete sufficient evaluation of 3 sites to select a site for expanded siting research activities and for other activities under section 218. The Secretary is authorized to conduct such preconstruction activities relative to such site selection for the test and evaluation facility as he deems appropriate. Additional sites for the location of the test and evaluation facility authorized in section 302(d) may be evaluated after such 30-month period, following the same procedures as if such sites were to be evaluated within such period.

(b) PUBLIC MEETINGS AND ENVIRONMENTAL ASSESSMENT.—Not later than 6 months after the date on which the Secretary completes the identification of sites under section 213, and before beginning siting research activities, the Secretary shall hold at least 1 public meeting in the vicinity of each site to inform the residents of the area of the activities to be conducted at such site and to receive their views.

(c) RESTRICTIONS.—Except as provided in section 218 with respect to a test and evaluation facility, in conducting siting research activities pursuant to subsection (a)—

(1) the Secretary shall use the minimum quantity of high-level radioactive waste or other radioactive materials, if any, necessary to achieve the test or research objectives;

(2) the Secretary shall ensure that any radioactive material used or placed on a site shall be fully retrievable; and

(3) upon termination of siting research activities at a site for any reason, the Secretary shall remove any radioactive material at or in the site as promptly as practicable.

(d) TITLE TO MATERIAL.—The Secretary may take title, in the name of the Federal Government, to the high-level radioactive waste, spent nuclear fuel, or other radioactive material emplaced in a test and evaluation facility. If the Secretary takes title to any such material, the Secretary shall enter into the appropriate financial arrangements described in subsection (a) or (b) of section 302 for the disposal of such material.

TEST AND EVALUATION FACILITY SITING REVIEW AND REPORTS

42 USC 10195.

SEC. 215. (a) CONSULTATION AND COOPERATION.—The Governor of a State, or the governing body of an affected Indian tribe, notified of a site identification under section 213 shall have the right to participate in a process of consultation and cooperation as soon as the site involved has been identified pursuant to such section and throughout the life of the test and evaluation facility. For purposes of this section, the term "process of consultation and cooperation" means a methodology—

"Process of consultation and cooperation."

(1) by which the Secretary—

(A) keeps the Governor or governing body involved fully and currently informed about any potential economic or public health and safety impacts in all stages of the siting, development, construction, and operation of a test and evaluation facility;

(B) solicits, receives, and evaluates concerns and objections of such Governor or governing body with regard to such test and evaluation facility on an ongoing basis; and

(C) works diligently and cooperatively to resolve such concerns and objections; and

(2) by which the State or affected Indian tribe involved can exercise reasonable independent monitoring and testing of onsite activities related to all stages of the siting, development, construction and operation of the test and evaluation facility, except that any such monitoring and testing shall not unreasonably interfere with onsite activities.

(b) Written Agreements.—The Secretary shall enter into written agreements with the Governor of the State in which an identified site is located or with the governing body of any affected Indian tribe where an identified site is located in order to expedite the consultation and cooperation process. Any such written agreement shall specify—

(1) procedures by which such Governor or governing body may study, determine, comment on, and make recommendations with regard to the possible health, safety, and economic impacts of the test and evaluation facility;

(2) procedures by which the Secretary shall consider and respond to comments and recommendations made by such Governor or governing body, including the period in which the Secretary shall so respond;

(3) the documents the Department is to submit to such Governor or governing body, the timing for such submissions, the timing for such Governor or governing body to identify public health and safety concerns and the process to be followed to try to eliminate those concerns;

(4) procedures by which the Secretary and either such Governor or governing body may review or modify the agreement periodically; and

(5) procedures for public notification of the procedures specified under subparagraphs (A) through (D).

(c) Limitation.—Except as specifically provided in this section, nothing in this title is intended to grant any State or affected Indian tribe any authority with respect to the siting, development, or loading of the test and evaluation facility.

FEDERAL AGENCY ACTIONS

42 USC 10196.

Sec. 216. (a) Cooperation and Coordination.—Federal agencies shall assist the Secretary by cooperating and coordinating with the Secretary in the preparation of any necessary reports under this title and the mission plan under section 301.

(b) Environmental Review.—(1) No action of the Secretary or any other Federal agency required by this title or section 301 with respect to a test and evaluation facility to be taken prior to the initiation of onsite construction of a test and evaluation facility shall require the preparation of an environmental impact statement under section 102(2)(C) of the Environmental Policy Act of 1969 (42

U.S.C. 4332(2)(C)), or to require the preparation of environmental reports, except as otherwise specifically provided for in this title.

(2) The Secretary and the heads of all other Federal agencies shall, to the maximum extent possible, avoid duplication of efforts in the preparation of reports under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.).

RESEARCH AND DEVELOPMENT ON DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE

42 USC 10197.

SEC. 217. (a) PURPOSE.—Not later than 64 months after the date of the enactment of this Act, the Secretary is authorized to, to the extent practicable, begin at a site evaluated under section 214, as part of and as an extension of siting research activities of such site under such section, the mining and construction of a test and evaluation facility. Prior to the mining and construction of such facility, the Secretary shall prepare an environmental assessment. The purpose of such facility shall be—

Environmental assessment.

(1) to supplement and focus the repository site characterization process;

(2) to provide the conditions under which known technological components can be integrated to demonstrate a functioning repository-like system;

(3) to provide a means of identifying, evaluating, and resolving potential repository licensing issues that could not be resolved during the siting research program conducted under section 212;

(4) to validate, under actual conditions, the scientific models used in the design of a repository;

(5) to refine the design and engineering of repository components and systems and to confirm the predicted behavior of such components and systems;

(6) to supplement the siting data, the generic and specific geological characteristics developed under section 214 relating to isolating disposal materials in the physical environment of a repository;

(7) to evaluate the design concepts for packaging, handling, and emplacement of high-level radioactive waste and spent nuclear fuel at the design rate; and

(8) to establish operating capability without exposing workers to excessive radiation.

(b) DESIGN.—The Secretary shall design each test and evaluation facility—

(1) to be capable of receiving not more than 100 full-sized canisters of solidified high-level radioactive waste (which canisters shall not exceed an aggregate weight of 100 metric tons), except that spent nuclear fuel may be used instead of such waste if such waste cannot be obtained under reasonable conditions;

(2) to permit full retrieval of solidified high-level radioactive waste, or other radioactive material used by the Secretary for testing, upon completion of the technology demonstration activities; and

(3) based upon the principle that the high-level radioactive waste, spent nuclear fuel, or other radioactive material involved shall be isolated from the biosphere in such a way that the

initial isolation is provided by engineered barriers functioning as a system with the geologic environment.

Testing.

(c) OPERATION.—(1) Not later than 88 months after the date of the enactment of this Act, the Secretary shall begin an in situ testing program at the test and evaluation facility in accordance with the mission plan developed under section 301, for purposes of—

(A) conducting in situ tests of bore hole sealing, geologic media fracture sealing, and room closure to establish the techniques and performance for isolation of high-level radioactive waste, spent nuclear fuel, or other radioactive materials from the biosphere;

(B) conducting in situ tests with radioactive sources and materials to evaluate and improve reliable models for radionuclide migration, absorption, and containment within the engineered barriers and geologic media involved, if the Secretary finds there is reasonable assurance that such radioactive sources and materials will not threaten the use of such site as a repository;

(C) conducting in situ tests to evaluate and improve models for ground water or brine flow through fractured geologic media;

(D) conducting in situ tests under conditions representing the real time and the accelerated time behavior of the engineered barriers within the geologic environment involved;

(E) conducting in situ tests to evaluate the effects of heat and pressure on the geologic media involved, on the hydrology of the surrounding area, and on the integrity of the disposal packages;

(F) conducting in situ tests under both normal and abnormal repository conditions to establish safe design limits for disposal packages and to determine the effects of the gross release of radionuclides into surroundings, and the effects of various credible failure modes, including—

(i) seismic events leading to the coupling of aquifers through the test and evaluation facility;

(ii) thermal pulses significantly greater than the maximum calculated; and

(iii) human intrusion creating a direct pathway to the biosphere; and

(G) conducting such other research and development activities as the Secretary considers appropriate, including such activities necessary to obtain the use of high-level radioactive waste, spent nuclear fuel, or other radioactive materials (such as any highly radioactive material from the Three Mile Island nuclear powerplant or from the West Valley Demonstration Project) for test and evaluation purposes, if such other activities are reasonably necessary to support the repository program and if there is reasonable assurance that the radioactive sources involved will not threaten the use of such site as a repository.

(2) The in situ testing authorized in this subsection shall be designed to ensure that the suitability of the site involved for licensing by the Commission as a repository will not be adversely affected.

(d) USE OF EXISTING DEPARTMENT FACILITIES.—During the conducting of siting research activities under section 214 and for such period thereafter as the Secretary considers appropriate, the Secretary shall use Department facilities owned by the Federal Government on the date of the enactment of this Act for the conducting of generically applicable tests regarding packaging, handling, and emplacement technology for solidified high-level radioactive waste and spent nuclear fuel from civilian nuclear activities.

(e) ENGINEERED BARRIERS.—The system of engineered barriers and selected geology used in a test and evaluation facility shall have a design life at least as long as that which the Commission requires by regulations issued under this Act, or under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.), for repositories.

(f) ROLE OF COMMISSION.—(1)(A) Not later than 1 year after the date of the enactment of this Act, the Secretary and the Commission shall reach a written understanding establishing the procedures for review, consultation, and coordination in the planning, construction, and operation of the test and evaluation facility under this section. Such understanding shall establish a schedule, consistent with the deadlines set forth in this subtitle, for submission by the Secretary of, and review by the Commission of and necessary action on—

(i) the mission plan prepared under section 301; and

(ii) such reports and other information as the Commission may reasonably require to evaluate any health and safety impacts of the test and evaluation facility.

(B) Such understanding shall also establish the conditions under which the Commission may have access to the test and evaluation facility for the purpose of assessing any public health and safety concerns that it may have. No shafts may be excavated for the test and evaluation until the Secretary and the Commission enter into such understanding.

(2) Subject to section 305, the test and evaluation facility, and the facilities authorized in section 217, shall be constructed and operated as research, development, and demonstration facilities, and shall not be subject to licensing under section 202 of the Energy Reorganization Act of 1974 (42 U.S.C. 5842).

(3)(A) The Commission shall carry out a continuing analysis of the activities undertaken under this section to evaluate the adequacy of the consideration of public health and safety issues.

(B) The Commission shall report to the President, the Secretary, and the Congress as the Commission considers appropriate with respect to the conduct of activities under this section.

(g) ENVIRONMENTAL REVIEW.—The Secretary shall prepare an environmental impact statement under section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)) prior to conducting tests with radioactive materials at the test and evaluation facility. Such environmental impact statement shall incorporate, to the extent practicable, the environmental assessment prepared under section 217(a). Nothing in this subsection may be construed to limit siting research activities conducted under section 214. This subsection shall apply only to activities performed exclusively for a test and evaluation facility.

(h) LIMITATIONS.—(1) If the test and evaluation facility is not located at the site of a repository, the Secretary shall obtain the concurrence of the Commission with respect to the decontamination and decommissioning of such facility.

(2) If the test and evaluation facility is not located at a candidate site or repository site, the Secretary shall conduct only the portion of the in situ testing program required in subsection (c) determined by the Secretary to be useful in carrying out the purposes of this Act.

Termination.

(3) The operation of the test and evaluation facility shall terminate not later than—

(A) 5 years after the date on which the initial repository begins operation; or

(B) at such time as the Secretary determines that the continued operation of a test and evaluation facility is not necessary for research, development, and demonstration purposes;

whichever occurs sooner.

(4) Notwithstanding any other provisions of this subsection, as soon as practicable following any determination by the Secretary, with the concurrence of the Commission, that the test and evaluation facility is unsuitable for continued operation, the Secretary shall take such actions as are necessary to remove from such site any radioactive material placed on such site as a result of testing and evaluation activities conducted under this section. Such requirement may be waived if the Secretary, with the concurrence of the Commission, finds that short-term testing and evaluation activities using radioactive material will not endanger the public health and safety.

RESEARCH AND DEVELOPMENT ON SPENT NUCLEAR FUEL

42 USC 10198.

SEC. 218. (a) DEMONSTRATION AND COOPERATIVE PROGRAMS.—The Secretary shall establish a demonstration program, in cooperation with the private sector, for the dry storage of spent nuclear fuel at civilian nuclear power reactor sites, with the objective of establishing one or more technologies that the Commission may, by rule, approve for use at the sites of civilian nuclear power reactors without, to the maximum extent practicable, the need for additional site-specific approvals by the Commission. Not later than 1 year after the date of the enactment of this Act, the Secretary shall select at least 1, but not more than 3, sites evaluated under section 214 at such power reactors. In selecting such site or sites, the Secretary shall give preference to civilian nuclear power reactors that will soon have a shortage of interim storage capacity for spent nuclear fuel. Subject to reaching agreement as provided in subsection (b), the Secretary shall undertake activities to assist such power reactors with demonstration projects at such sites, which may use one of the following types of alternate storage technologies: spent nuclear fuel storage casks, caissons, or silos. The Secretary shall also undertake a cooperative program with civilian nuclear power reactors to encourage the development of the technology for spent nuclear fuel rod consolidation in existing power reactor water storage basins.

(b) COOPERATIVE AGREEMENTS.—To carry out the programs described in subsection (a), the Secretary shall enter into a cooperative agreement with each utility involved that specifies, at a minimum, that—

(1) such utility shall select the alternate storage technique to be used, make the land and spent nuclear fuel available for the dry storage demonstration, submit and provide site-specific documentation for a license application to the Commission, obtain a license relating to the facility involved, construct such facility, operate such facility after licensing, pay the costs required to construct such facility, and pay all costs associated with the operation and maintenance of such facility;

(2) the Secretary shall provide, on a cost-sharing basis, consultative and technical assistance, including design support

and generic licensing documentation, to assist such utility in obtaining the construction authorization and appropriate license from the Commission; and

(3) the Secretary shall provide generic research and development of alternative spent nuclear fuel storage techniques to enhance utility-provided, at-reactor storage capabilities, if authorized in any other provision of this Act or in any other provision of law.

(c) Dry Storage Research and Development.—(1) The consultative and technical assistance referred to in subsection (b)(2) may include, but shall not be limited to, the establishment of a research and development program for the dry storage of not more than 300 metric tons of spent nuclear fuel at facilities owned by the Federal Government on the date of the enactment of this Act. The purpose of such program shall be to collect necessary data to assist the utilities involved in the licensing process.

(2) To the extent available, and consistent with the provisions of section 135, the Secretary shall provide spent nuclear fuel for the research and development program authorized in this subsection from spent nuclear fuel received by the Secretary for storage under section 135. Such spent nuclear fuel shall not be subject to the provisions of section 135(e).

(d) Funding.—The total contribution from the Secretary from Federal funds and the use of Federal facilities or services shall not exceed 25 percent of the total costs of the demonstration program authorized in subsection (a), as estimated by the Secretary. All remaining costs of such program shall be paid by the utilities involved or shall be provided by the Secretary from the Interim Storage Fund established in section 136.

(e) Relation to Spent Nuclear Fuel Storage Program.—The spent nuclear fuel storage program authorized in section 135 shall not be construed to authorize the use of research development or demonstration facilities owned by the Department unless—

Report to congressional committees.

(1) a period of 30 calendar days (not including any day in which either House of Congress is not in session because of adjournment of more than 3 calendar days to a day certain) has passed after the Secretary has transmitted to the Committee on Science and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate a written report containing a full and complete statement concerning (A) the facility involved; (B) any necessary modifications; (C) the cost thereof; and (D) the impact on the authorized research and development program; or

(2) each such committee, before the expiration of such period, has transmitted to the Secretary a written notice to the effect that such committee has no objection to the proposed use of such facility.

PAYMENTS TO STATES AND INDIAN TRIBES

42 USC 10199.

Sec. 219. (a) Payments.—Subject to subsection (b), the Secretary shall make payments to each State or affected Indian tribe that has entered into an agreement pursuant to section 215. The Secretary shall pay an amount equal to 100 percent of the expenses incurred by such State or Indian tribe in engaging in any monitoring, testing, evaluation, or other consultation and cooperation activity under section 215 with respect to any site. The amount paid by the

Secretary under this paragraph shall not exceed $3,000,000 per year from the date on which the site involved was identified to the date on which the decontamination and decommission of the facility is complete pursuant to section 217(h). Any such payment may only be made to a State in which a potential site for a test and evaluation facility has been identified under section 213, or to an affected Indian tribe where the potential site has been identified under such section.

(b) LIMITATION.—The Secretary shall make any payment to a State under subsection (a) only if such State agrees to provide, to each unit of general local government within the jurisdictional boundaries of which the potential site or effectively selected site involved is located, at least one-tenth of the payments made by the Secretary to such State under such subsection. A State or affected Indian tribe receiving any payment under subsection (a) shall otherwise have discretion to use such payment for whatever purpose it deems necessary, including the State or tribal activities pursuant to agreements entered into in accordance with section 215. Annual payments shall be prorated on a 365-day basis to the specified dates.

STUDY OF RESEARCH AND DEVELOPMENT NEEDS FOR MONITORED RETRIEVABLE STORAGE PROPOSAL

Report to Congress.
42 USC 10200.

SEC. 220. Not later than 6 months after the date of the enactment of this Act, the Secretary shall submit to the Congress a report describing the research and development activities the Secretary considers necessary to develop the proposal required in section 141(b) with respect to a monitored retrievable storage facility.

JUDICIAL REVIEW

42 USC 10201.
Ante, p. 2227.

SEC. 221. Judicial review of research and development activities under this title shall be in accordance with the provisions of section 119.

42 USC 10202.

SEC. 222. RESEARCH ON ALTERNATIVES FOR THE PERMANENT DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE.—The Secretary shall continue and accelerate a program of research, development, and investigation of alternative means and technologies for the permanent disposal of high-level radioactive waste from civilian nuclear activities and Federal research and development activities except that funding shall be made from amounts appropriated to the Secretary for purposes of carrying out this section. Such program shall include examination of various waste disposal options.

TECHNICAL ASSISTANCE TO NON-NUCLEAR WEAPON STATES IN THE FIELD OF SPENT FUEL STORAGE AND DISPOSAL

42 USC 10203.

SEC. 223. (a) It shall be the policy of the United States to cooperate with and provide technical assistance to non-nuclear weapon states in the field of spent fuel storage and disposal.

Joint notice, publication in Federal Register.

(b)(1) Within 90 days of enactment of this Act, the Secretary and the Commission shall publish a joint notice in the Federal Register stating that the United States is prepared to cooperate with and provide technical assistance to non-nuclear weapon states in the fields of at-reactor spent fuel storage; away-from-reactor spent fuel storage; monitored, retrievable spent fuel storage; geologic disposal of spent fuel; and the health, safety, and environmental regulation of such activities. The notice shall summarize the resources that can be made available for international cooperation and assistance in these fields through existing programs of the Department and the Commission, including the availability of: (i) data from past or ongoing research and development projects; (ii) consultations with expert Department or Commission personnel or contractors; and (iii) liaison with private business entities and organizations working in these fields.

Joint notice, reissuance.

(2) The joint notice described in the preceding subparagraph shall be updated and reissued annually for 5 succeeding years.

Expressions of interest.

(c) Following publication of the annual joint notice referred to in paragraph (2), the Secretary of State shall inform the governments of non-nuclear weapon states and, as feasible, the organizations operating nuclear powerplants in such states, that the United States is prepared to cooperate with and provide technical assistance to non-nuclear weapon states in the fields of spent fuel storage and disposal, as set forth in the joint notice. The Secretary of State shall also solicit expressions of interest from non-nuclear weapon state governments and non-nuclear weapon state nuclear power reactor operators concerning their participation in expanded United States cooperation and technical assistance programs in these fields. The Secretary of State shall transmit any such expressions of interest to the Department and the Commission.

(d) With his budget presentation materials for the Department and the Commission for fiscal years 1984 through 1989, the President shall include funding requests for an expanded program of cooperation and technical assistance with non-nuclear weapon states in the fields of spent fuel storage and disposal as appropriate in light of expressions of interest in such cooperation and assistance on the part of non-nuclear weapon state governments and non-nuclear weapon state nuclear power reactor operators.

"Non-nuclear weapon state."

(e) For the purposes of this subsection, the term "non-nuclear weapon state" shall have the same meaning as that set forth in article IX of the Treaty on the Non-Proliferation of Nuclear Weapons (21 U.S.C. 438).

(f) Nothing in this subsection shall authorize the Department or the Commission to take any action not authorized under existing law.

TITLE III—OTHER PROVISIONS RELATING TO RADIOACTIVE WASTE

MISSION PLAN

42 USC 10221.

SEC. 301. (a) CONTENTS OF MISSION PLAN.—The Secretary shall prepare a comprehensive report, to be known as the mission plan, which shall provide an informational basis sufficient to permit informed decisions to be made in carrying out the repository program and the research, development, and demonstration programs required under this Act. The mission plan shall include—

(1) an identification of the primary scientific, engineering, and technical information, including any necessary demonstration of engineering or systems integration, with respect to the siting and construction of a test and evaluation facility and repositories;

(2) an identification of any information described in paragraph (1) that is not available because of any unresolved scien-

tific, engineering, or technical questions, or undemonstrated engineering or systems integration, a schedule including specific major milestones for the research, development, and technology demonstration program required under this Act and any additional activities to be undertaken to provide such information, a schedule for the activities necessary to achieve important programmatic milestones, and an estimate of the costs required to carry out such research, development, and demonstration programs;

(3) an evaluation of financial, political, legal, or institutional problems that may impede the implementation of this Act, the plans of the Secretary to resolve such problems, and recommendations for any necessary legislation to resolve such problems;

(4) any comments of the Secretary with respect to the purpose and program of the test and evaluation facility;

(5) a discussion of the significant results of research and development programs conducted and the implications for each of the different geologic media under consideration for the siting of repositories, and, on the basis of such information, a comparison of the advantages and disadvantages associated with the use of such media for repository sites;

Ante, p. 2208.

(6) the guidelines issued under section 112(a);

(7) a description of known sites at which site characterization activities should be undertaken, a description of such siting characterization activities, including the extent of planned excavations, plans for onsite testing with radioactive or nonradioactive material, plans for any investigations activities which may affect the capability of any such site to isolate high-level radioactive waste or spent nuclear fuel, plans to control any adverse, safety-related impacts from such site characterization activities, and plans for the decontamination and decommissioning of such site if it is determined unsuitable for licensing as a repository;

(8) an identification of the process for solidifying high-level radioactive waste or packaging spent nuclear fuel, including a summary and analysis of the data to support the selection of the solidification process and packaging techniques, an analysis of the requirements for the number of solidification packaging facilities needed, a description of the state of the art for the materials proposed to be used in packaging such waste or spent fuel and the availability of such materials including impacts on strategic supplies and any requirements for new or reactivated facilities to produce any such materials needed, and a description of a plan, and the schedule for implementing such plan, for an aggressive research and development program to provide when needed a high-integrity disposal package at a reasonable price;

(9) an estimate of (A) the total repository capacity required to safely accommodate the disposal of all high-level radioactive waste and spent nuclear fuel expected to be generated through December 31, 2020, in the event that no commercial reprocessing of spent nuclear fuel occurs, as well as the repository capacity that will be required if such reprocessing does occur; (B) the number and type of repositories required to be constructed to provide such disposal capacity; (C) a schedule for the construction of such repositories; and (D) an estimate of the period during which each repository listed in such schedule will

be accepting high-level radioactive waste or spent nuclear fuel for disposal;

(10) an estimate, on an annual basis, of the costs required (A) to construct and operate the repositories anticipated to be needed under paragraph (9) based on each of the assumptions referred to in such paragraph; (B) to construct and operate a test and evaluation facility, or any other facilities, other than repositories described in subparagraph (A), determined to be necessary; and (C) to carry out any other activities under this Act; and

(11) an identification of the possible adverse economic and other impacts to the State or Indian tribe involved that may arise from the development of a test and evaluation facility or repository at a site.

(b) Submission of Mission Plan.—(1) Not later than 15 months after the date of the enactment of this Act, the Secretary shall submit a draft mission plan to the States, the affected Indian tribes, the Commission, and other Government agencies as the Secretary deems appropriate for their comments.

Publication in Federal Register. Public inspection and agency comments.

(2) In preparing any comments on the mission plan, such agencies shall specify with precision any objections that they may have. Upon submission of the mission plan to such agencies, the Secretary shall publish a notice in the Federal Register of the submission of the mission plan and of its availability for public inspection, and, upon receipt of any comments of such agencies respecting the mission plan, the Secretary shall publish a notice in the Federal Register of the receipt of comments and of the availability of the comments for public inspection. If the Secretary does not revise the mission plan to meet objections specified in such comments, the Secretary shall publish in the Federal Register a detailed statement for not so revising the mission plan.

Plan submittal to congressional committees.

(3) The Secretary, after reviewing any other comments made by such agencies and revising the mission plan to the extent that the Secretary may consider to be appropriate, shall submit the mission plan to the appropriate committees of the Congress not later than 17 months after the date of the enactment of this Act. The mission plan shall be used by the Secretary at the end of the first period of 30 calendar days (not including any day on which either House of Congress is not in session because of adjournment of more than 3 calendar days to a day certain) following receipt of the mission plan by the Congress.

NUCLEAR WASTE FUND

42 USC 10222.

Sec. 302. (a) Contracts.—(1) In the performance of his functions under this Act, the Secretary is authorized to enter into contracts with any person who generates or holds title to high-level radioactive waste, or spent nuclear fuel, of domestic origin for the acceptance of title, subsequent transportation, and disposal of such waste or spent fuel. Such contracts shall provide for payment to the Secretary of fees pursuant to paragraphs (2) and (3) sufficient to offset expenditures described in subsection (d).

Fees.

(2) For electricity generated by a civilian nuclear power reactor and sold on or after the date 90 days after the date of enactment of this Act, the fee under paragraph (1) shall be equal to 1.0 mil per kilowatt-hour.

Fees.

(3) For spent nuclear fuel, or solidified high-level radioactive waste derived from spent nuclear fuel, which fuel was used to generate electricity in a civilian nuclear power reactor prior to the application of the fee under paragraph (2) to such reactor, the Secretary shall, not later than 90 days after the date of enactment of this Act, establish a 1 time fee per kilogram of heavy metal in spent nuclear fuel, or in solidified high-level radioactive waste. Such fee shall be in an amount equivalent to an average charge of 1.0 mil per kilowatt-hour for electricity generated by such spent nuclear fuel, or such solidified high-level waste derived therefrom, to be collected from any person delivering such spent nuclear fuel or high-level waste, pursuant to section 123, to the Federal Government. Such fee shall be paid to the Treasury of the United States and shall be deposited in the separate fund established by subsection (c) 126(b). In paying such a fee, the person delivering spent fuel, or solidified high-level radioactive wastes derived therefrom, to the Federal Government shall have no further financial obligation to the Federal Government for the long-term storage and permanent disposal of such spent fuel, or the solidified high-level radioactive waste derived therefrom.

Ante, p. 2229.

Collection and payment procedures. Review.

(4) Not later than 180 days after the date of enactment of this Act, the Secretary shall establish procedures for the collection and payment of the fees established by paragraph (2) and paragraph (3). The Secretary shall annually review the amount of the fees established by paragraphs (2) and (3) above to evaluate whether collection of the fee will provide sufficient revenues to offset the costs as defined in subsection (d) herein. In the event the Secretary determines that either insufficient or excess revenues are being collected, in order to recover the costs incurred by the Federal Government that are specified in subsection (d), the Secretary shall propose an adjustment to the fee to insure full cost recovery. The Secretary shall immediately transmit this proposal for such an adjustment to Congress. The adjusted fee proposed by the Secretary shall be effective after a period of 90 days of continuous session have elapsed following the receipt of such transmittal unless during such 90-day period either House of Congress adopts a resolution disapproving the Secretary's proposed adjustment in accordance with the procedures set forth for congressional review of an energy action under section 551 of the Energy Policy and Conservation Act.

Transmittal to Congress.

42 USC 6421.

(5) Contracts entered into under this section shall provide that—

(A) following commencement of operation of a repository, the Secretary shall take title to the high-level radioactive waste or spent nuclear fuel involved as expeditiously as practicable upon the request of the generator or owner of such waste or spent fuel; and

(B) in return for the payment of fees established by this section, the Secretary, beginning not later than January 31, 1998, will dispose of the high-level radioactive waste or spent nuclear fuel involved as provided in this subtitle.

Disposal services, terms and conditions.

(6) The Secretary shall establish in writing criteria setting forth the terms and conditions under which such disposal services shall be made available.

License renewal or issuance.

(b) ADVANCE CONTRACTING REQUIREMENT.—(1)(A) The Commission shall not issue or renew a license to any person to use a utilization or production facility under the authority of section 103 or 104 of the Atomic Energy Act of 1954 (42 U.S.C. 2133, 2134) unless—

(i) such person has entered into a contract with the Secretary under this section; or

(ii) the Secretary affirms in writing that such person is actively and in good faith negotiating with the Secretary for a contract under this section.

(B) The Commission, as it deems necessary or appropriate, may require as a precondition to the issuance or renewal of a license under section 103 or 104 of the Atomic Energy Act of 1954 (42 U.S.C. 2133, 2134) that the applicant for such license shall have entered into an agreement with the Secretary for the disposal of high-level radioactive waste and spent nuclear fuel that may result from the use of such license.

(2) Except as provided in paragraph (1), no spent nuclear fuel or high-level radioactive waste generated or owned by any person (other than a department of the United States referred to in section 101 or 102 of title 5, United States Code) may be disposed of by the Secretary in any repository constructed under this Act unless the generator or owner of such spent fuel or waste has entered into a contract with the Secretary under this section by not later than—

(A) June 30, 1983; or

(B) the date on which such generator or owner commences generation of, or takes title to, such spent fuel or waste;

whichever occurs later.

(3) The rights and duties of a party to a contract entered into under this section may be assignable with transfer of title to the spent nuclear fuel or high-level radioactive waste involved.

Disposal of radioactive waste or spent nuclear fuel.

(4) No high-level radioactive waste or spent nuclear fuel generated or owned by any department of the United States referred to in section 101 or 102 of title 5, United States Code, may be disposed of by the Secretary in any repository constructed under this Act unless such department transfers to the Secretary, for deposit in the Nuclear Waste Fund, amounts equivalent to the fees that would be paid to the Secretary under the contracts referred to in this section if such waste or spent fuel were generated by any other person.

(c) Establishment of Nuclear Waste Fund.—There hereby is established in the Treasury of the United States a separate fund, to be known as the Nuclear Waste Fund. The Waste Fund shall consist of—

(1) all receipts, proceeds, and recoveries realized by the Secretary under subsections (a), (b), and (e), which shall be deposited in the Waste Fund immediately upon their realization;

(2) any appropriations made by the Congress to the Waste Fund; and

(3) any unexpended balances available on the date of the enactment of this Act for functions or activities necessary or incident to the disposal of civilian high-level radioactive waste or civilian spent nuclear fuel, which shall automatically be transferred to the Waste Fund on such date.

(d) Use of Waste Fund.—The Secretary may make expenditures from the Waste Fund, subject to subsection (e), only for purposes of radioactive waste disposal activities under titles I and II, including—

Ante, pp. 2206, 2245.

(1) the identification, development, licensing, construction, operation, decommissioning, and post-decommissioning maintenance and monitoring of any repository, monitored, retrievable storage facility or test and evaluation facility constructed under this Act;

(2) the conducting of nongeneric research, development, and demonstration activities under this Act;

(3) the administrative cost of the radioactive waste disposal program;

(4) any costs that may be incurred by the Secretary in connection with the transportation, treating, or packaging of spent nuclear fuel or high-level radioactive waste to be disposed of in a repository, to be stored in a monitored, retrievable storage site or to be used in a test and evaluation facility;

(5) the costs associated with acquisition, design, modification, replacement, operation, and construction of facilities at a repository site, a monitored, retrievable storage site or a test and evaluation facility site and necessary or incident to such repository, monitored, retrievable storage facility or test and evaluation facility; and

(6) the provision of assistance to States, units of general local government, and Indian tribes under sections 116, 118, and 219.

Ante, pp. 2220, 2225, 2253.

No amount may be expended by the Secretary under this subtitle for the construction or expansion of any facility unless such construction or expansion is expressly authorized by this or subsequent legislation. The Secretary hereby is authorized to construct one repository and one test and evaluation facility.

Report to Congress.

(e) Administration of Waste Fund.—(1) The Secretary of the Treasury shall hold the Waste Fund and, after consultation with the Secretary, annually report to the Congress on the financial condition and operations of the Waste Fund during the preceding fiscal year.

Budget submittal.

Ante, p. 907.

(2) The Secretary shall submit the budget of the Waste Fund to the Office of Management and Budget triennially along with the budget of the Department of Energy submitted at such time in accordance with chapter 11 of title 31, United States Code. The budget of the Waste Fund shall consist of the estimates made by the Secretary of expenditures from the Waste Fund and other relevant financial matters for the succeeding 3 fiscal years, and shall be included in the Budget of the United States Government. The Secretary may make expenditures from the Waste Fund, subject to appropriations which shall remain available until expended. Appropriations shall be subject to triennial authorization.

(3) If the Secretary determines that the Waste Fund contains at any time amounts in excess of current needs, the Secretary may request the Secretary of the Treasury to invest such amounts, or any portion of such amounts as the Secretary determines to be appropriate, in obligations of the United States—

(A) having maturities determined by the Secretary of the Treasury to be appropriate to the needs of the Waste Fund; and

(B) bearing interest at rates determined to be appropriate by the Secretary of the Treasury, taking into consideration the current average market yield on outstanding marketable obligations of the United States with remaining periods to maturity comparable to the maturities of such investments, except that the interest rate on such investments shall not exceed the average interest rate applicable to existing borrowings.

(4) Receipts, proceeds, and recoveries realized by the Secretary under this section, and expenditures of amounts from the Waste Fund, shall be exempt from annual apportionment under the provisions of subchapter II of chapter 15 of title 31, United States Code.

Ante, p. 927.

(5) If at any time the moneys available in the Waste Fund are insufficient to enable the Secretary to discharge his responsibilities under this subtitle, the Secretary shall issue to the Secretary of the Treasury obligations in such forms and denominations, bearing such maturities, and subject to such terms and conditions as may be agreed to by the Secretary and the Secretary of the Treasury. The total of such obligations shall not exceed amounts provided in appropriation Acts. Redemption of such obligations shall be made by the Secretary from moneys available in the Waste Fund. Such obligations shall bear interest at a rate determined by the Secretary of the Treasury, which shall be not less than a rate determined by taking into consideration the average market yield on outstanding marketable obligations of the United States of comparable maturities during the month preceding the issuance of the obligations under this paragraph. The Secretary of the Treasury shall purchase any issued obligations, and for such purpose the Secretary of the Treasury is authorized to use as a public debt transaction the proceeds from the sale of any securities issued under chapter 31 of title 31, United States Code, and the purposes for which securities may be issued under such Act are extended to include any purchase of such obligations. The Secretary of the Treasury may at any time sell any of the obligations acquired by him under this paragraph. All redemptions, purchases, and sales by the Secretary of the Treasury of obligations under this paragraph shall be treated as public debt transactions of the United States.

Ante, p. 937.

Interest payments.

(6) Any appropriations made available to the Waste Fund for any purpose described in subsection (d) shall be repaid into the general fund of the Treasury, together with interest from the date of availability of the appropriations until the date of repayment. Such interest shall be paid on the cumulative amount of appropriations available to the Waste Fund, less the average undisbursed cash balance in the Waste Fund account during the fiscal year involved. The rate of such interest shall be determined by the Secretary of the Treasury taking into consideration the average market yield during the month preceding each fiscal year on outstanding marketable obligations of the United States of comparable maturity. Interest payments may be deferred with the approval of the Secretary of the Treasury, but any interest payments so deferred shall themselves bear interest.

Deferral.

ALTERNATIVE MEANS OF FINANCING

Study.
42 USC 10223.

SEC. 303. The Secretary shall undertake a study with respect to alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities, including the feasibility of establishing a private corporation for such purposes. In conducting such study, the Secretary shall consult with the Director of the Office of Management and Budget, the Chairman of the Commission, and such other Federal agency representatives as may be appropriate. Such study shall be completed, and a report containing the results of such study shall be submitted to the Congress, within 1 year after the date of the enactment of this Act.

Report to Congress.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

42 USC 10224.

SEC. 304. (a) ESTABLISHMENT.—There hereby is established within the Department of Energy an Office of Civilian Radioactive Waste

Management. The Office shall be headed by a Director, who shall be appointed by the President, by and with the advice and consent of the Senate, and who shall be compensated at the rate payable for level IV of the Executive Schedule under section 5315 of title 5, United States Code.

(b) FUNCTIONS OF DIRECTOR.—The Director of the Office shall be responsible for carrying out the functions of the Secretary under this Act, subject to the general supervision of the Secretary. The Director of the Office shall be directly responsible to the Secretary.

(c) ANNUAL REPORT TO CONGRESS.—The Director of the Office shall annually prepare and submit to the Congress a comprehensive report on the activities and expenditures of the Office.

(d) ANNUAL AUDIT BY COMPTROLLER GENERAL.—The Comptroller General of the United States shall annually make an audit of the Office, in accordance with such regulations as the Comptroller General may prescribe. The Comptroller General shall have access to such books, records, accounts, and other materials of the Office as the Comptroller General determines to be necessary for the preparation of such audit. The Comptroller General shall submit to the Congress a report on the results of each audit conducted under this section.

Report to Congress

LOCATION OF TEST AND EVALUATION FACILITY

42 USC 10225.

SEC. 305. (a) REPORT TO CONGRESS.—Not later than 1 year after the date of the enactment of this Act, the Secretary shall transmit to the Congress a report setting forth whether the Secretary plans to locate the test and evaluation facility at the site of a repository.

(b) PROCEDURES.—(1) If the test and evaluation facility is to be located at any candidate site or repository site (A) site selection and development of such facility shall be conducted in accordance with the procedures and requirements established in title I with respect to the site selection and development of repositories; and (B) the Secretary may not commence construction of any surface facility for such test and evaluation facility prior to issuance by the Commission of a construction authorization for a repository at the site involved.

Ante, p. 2206.

(2) No test and evaluation facility may be converted into a repository unless site selection and development of such facility was conducted in accordance with the procedures and requirements established in title I with respect to the site selection and development of respositories.

(3) The Secretary may not commence construction of a test and evaluation facility at a candidate site or site recommended as the location for a repository prior to the date on which the designation of such site is effective under section 115.

Ante, p. 2217.

NUCLEAR REGULATORY COMMISSION TRAINING AUTHORIZATION

Regulations or guidance.
42 USC 10226.

SEC. 306. NUCLEAR REGULATORY COMMISSION TRAINING AUTHORIZATION.—The Nuclear Regulatory Commission is authorized and directed to promulgate regulations, or other appropriate Commission regulatory guidance, for the training and qualifications of civilian nuclear powerplant operators, supervisors, technicians and other appropriate operating personnel. Such regulations or guidance shall establish simulator training requirements for applicants for civilian nuclear powerplant operator licenses and for operator requalification programs; requirements governing NRC administration of requalification examinations; requirements for operating tests at civilian nuclear powerplant simulators, and instructional requirements for civilian nuclear powerplant licensee personnel training programs. Such regulations or other regulatory guidance shall be promulgated by the Commission within the 12-month period following enactment of this Act, and the Commission within the 12-month period following enactment of this Act shall submit a report to Congress setting forth the actions the Commission has taken with respect to fulfilling its obligations under this section.

Report to Congress.

Approved January 7, 1983.

LEGISLATIVE HISTORY—H.R. 3809:

HOUSE REPORT No. 97-491 pt.1 (Comm. on Interior and Insular Affairs) and pt. 2 (Comm. on Armed Services).
CONGRESSIONAL RECORD, Vol. 128 (1982):
  Sept. 30, Nov. 29, 30, Dec. 2, considered and passed House.
  Dec. 20, considered and passed Senate, amended; House agreed to Senate amendments.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 19, No. 1 (1983):
  Jan. 7, Presidential statement.

Appendix D

Performance Requirements for a Geologic Repository as Specified in Nuclear Regulatory Commission Regulation 10 CFR Part 60

Paragraph	*Performance requirement*
60.113(a)(1)	**Engineered Barrier System**—Containment of the high-level waste within the waste package must be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission products decay. Such period would be between 300 and 1,000 years as determined by the NRC for individual cases according to factors specified in 60.113(b). Any subsequent release of radionuclides shall be a gradual process of small fractional releases to the geologic setting over long periods of time. For disposal in the saturated zone, both partial and complete filling with ground water of available void spaces in the underground facility shall be appropriately considered and analyzed among the anticipated processes and events in designing the engineered barrier system. The release rate for any radionuclide shall not exceed 10^{-5} per year of its inventory calculated to be present 1,000 years after emplacement [60.113(a)(1)(B)]. This requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste originally emplaced in the underground facility that remains after 1,000 years of radioactive decay. Other fractional release limits may be specified by NRC for individual cases [60.113(b)].
60.113(a)(2)	**Geologic Setting**—The repository shall be located so that pre-waste-emplacement ground water travel time from the disturbed zone to the accessible environment shall be at least 1,000 years, or other travel time approved or specified by the Commission [60.113(b)].
60.113(b)	On a case-by-case basis NRC may determine the required waste package containment period, subsequent radioactive nuclide release rates, or pre-waste-emplacement ground water travel time, taking into account the overall system performance objective and factors such as the following: —generally applicable EPA standards for radioactivity; —age and nature of waste as well as design of the underground facility, particularly with respect to the time when the thermal pulse is dominated by the decay heat of fission products; —geochemical characteristics of the host rock, surrounding strata, and ground water; and —particular sources of uncertainty in predicting the repository performance.
60.131	General design criteria for the geologic repository operations area.
60.131(a)	**Radiological Protection**—The geologic repository operation area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air-restricted[1] areas within the limits specified in part 20[2] of this chapter.
60.131(b)	**Structures, Systems, and Components Important to Safety**—The repository system must include the following protective features: —protection against anticipated natural phenomena and environmental conditions, —protection against dynamic effects of equipment failure and similar events,

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[1] A restricted area is any area, access to which is controlled for purposes of protection of individuals from exposure to radiation.

[2] 10 CFR 20 establishes standards for protection against radiation hazards from licensed activities. Standards are established to protect both the workers and the general public.

SOURCE: U.S. Department of Energy.

Paragraph	*Performance requirement*
	—protection against fires and explosions,
	—emergency capability,
	—utility services under normal and accident conditions,
	—periodic inspection testing and maintenance,
	—control against critical conditions under normal and accidental conditions,
	—instrumentation and control systems,
	—compliance with mining regulations,
	—safe shaft conveyances for radioactive waste handling.

Appendix E

Procedure for Establishing a Repository for Commercial Nuclear Waste

Procedural step	*Governing law or regulation*
Site Selection:	
• Secretary of DOE issues guidelines.	NWPA—sec. 112(a)
• Secretary of DOE nominates at least five sites for characterization, accompanied by environmental assessment.	NWPA—sec. 112(b)(1)(A), (E)
• Secretary of DOE recommends to the President three of at least five sites for site characterization.	NWPA—sec. 112(b)(1)(B)
• President approves or disapproves recommended sites for site characterization.	NWPA—sec. 112(c)(1)
• President may delay decision for 6 months.	NWPA—sec. 112(c)(2)
• Secretary of DOE submits site characterization plan.	NWPA—sec. 113(b)(1)
• NRC prepares site characterization analysis.	10 CFR 60.11(d),(e),(f)
• DOE submits semiannual progress reports to Congress and NRC during site characterization activities.	NWPA—sec. 113(b)(3) 10 CFR 60.11(g)
• Secretary of DOE submits recommendation of a site for development of a repository to President, accompanied by supporting documentation and an Environmental Impact Statement.	NWPA—sec. 114(a),(f)
• President may submit request to Congress to delay recommendation of a site for a repository.	NWPA—sec. 114(a)(2)(B)
• President submits recommendation to Congress for the site to be developed as a repository.	NWPA—sec. 114(a)(2)(A)
• State or affected Indian tribe may submit notice of disapproval of site to Congress within 60 days.	NWPA—secs. 115(b), 116(b), 118(a)
• Congress may override disapproval notice within 90 days of continuous session.	NWPA—sec. 115(c)
• If first site recommended is not approved, President must submit another recommendation within 1 year after disapproval.	NWPA—sec. 114(a)(3)
Construction Authorization and License:	
• Following site designation and within 90 days after approval by Congress, the Secretary of DOE submits an application for construction authorization to NRC.	NWPA—secs. 114(b), 115
• NRC submits annual progress reports to Congress on status of application.	NWPA—sec. 114(c)
• NRC may adopt Environmental Impact Statement of DOE to fulfill its obligation to prepare same.	NWPA—sec. 114(f)
• NRC may approve or disapprove issuance of construction authorization.	NWPA—sec. 114(d)
• NRC must issue final decision on application within 3 years after application is submitted. Decision may be delayed up to one additional year.	NWPA—sec. 114(d)
Consultation and Cooperation by States, Affected Indian Tribes, and Public:	
• States or affected Indian tribes must be notified and public hearings held prior to site nomination.	NWPA secs. 112(b)(1)(H); 112(b)(2)

Procedural step	*Governing law or regulation*
• The Secretary of DOE must seek to enter into binding written agreement with State or affected Indian tribe regarding procedures for consultation and cooperation.	NWPA—sec. 117(c)
• President or Secretary of DOE must submit notice to State or affected Indian tribe regarding decisions on sites recommended by DOE for characterization.	NWPA—sec. 112(c)
• Secretary of DOE must submit copies of site characterization plan to States or affected Indian tribe for their review and comment.	NWPA—sec. 113(b)
• Secretary of DOE must submit semiannual reports on site characterization activities to State or affected Indian tribe.	NWPA—sec. 113(b)(3)
• DOE must notify State or affected Indian tribe if site characterization activities are terminated.	NWPA—sec. 113(c)(3)
• The Secretary of DOE must conduct public hearings at each site under consideration prior to recommending a site for a repository.	NWPA—sec. 114(a)(1)
• Secretary of DOE must notify State or affected Indian tribe prior to recommending a site for a repository.	NWPA—sec. 114(a)(1)
• State or affected Indian tribe may submit notice of disapproval of site to Congress.	NWPA—secs. 116(b), 118(a)
• Site is disapproved unless Congress passes a joint resolution of repository siting approval within 90 days of continuous session.	NWPA—sec. 115(c)
• State or affected Indian tribe must be provided with a copy of the application for construction authorization.	NWPA—sec. 114(b)
Scheduling:	
• Secretary of DOE must prepare project decision schedule.	NWPA—sec. 114(e)(1)
• Agencies that cannot comply with schedule must so notify Secretary of DOE and Congress.	NWPA—sec. 114(e)(2)
Funding:	
• All costs paid out of Nuclear Waste Fund.	NWPA—secs. 116(c)(5), 18(b)(6); 302(d)
• Cost for disposal of defense high-level waste will be paid into Nuclear Waste Fund by Federal Government.	NWPA—secs. 8(b)(2), 302(b)(4)

SOURCE: U.S. Department of Energy.

Appendix F
Spent Fuel Projections

Each table provides the following information for each year out to the projected end of life for all plants involved:

- the projected annual spent fuel discharges;
- the projected cumulative spent fuel inventories; and
- the projected annual and cumulative requirements for additional storage capacity outside of the reactor basin, based on the "maximum at-reactor capacity" case. (See U.S. Department of Energy, *Spent Fuel Storage Requirements,* DOE-RL-83-1. These data are based on inventories and projections as of Sept. 30, 1982.)

All results are given both in number of assemblies and in metric tons of uranium. The inventories as of Dec. 31, 1982, are given in the first line of table F-1. (No such inventories exist for the light-water-reactors that are not currently operating.)

The cumulative inventories given in tables F-1 and F-2 do not include spent fuel that is currently stored at the West Valley and GE-Morris facilities. A breakdown of this fuel is as follows:

	West Valley		*GE-Morris*	
	MTU	*Assemblies*	*MTU*	*Assemblies*
Boiling-water reactor	75.1	515	141.6	753
Pressurized-water reactor	93.4	235	177.3	459
Totals	168.5	750	318.9	1,212
Aggregate totals:			487.4	1,962

The cumulative inventories also do not include any corrections for possible future shipments of spent fuel to or from nonreactor destinations, because there are no accurate projections of such shipments. Any such shipments would reduce requirements for additional spent fuel storage at reactor sites.

The assumed storage capacity of existing basins does not reflect potential technical measures that can increase the pool capacity, including burnup credit reracking and rod consolidation.

Table F-1.—Spent Fuel Storage Projections: Total Currently Operating Light-Water Reactors

	Annual discharge		Cumulative inventory		Annual storage[a] requirements		Cumulative storage requirements	
Year	Tonnes	Assemblies	Tonnes	Assemblies	Tonnes	Assemblies	Tonnes	Assemblies
1982	—	—	8,507	31,260	0	0	0	0
1983	1,301	4,595	9,808	35,855	0	0	0	0
1984	1,427	4,903	11,234	40,758	13	28	13	28
1985	1,391	4,804	12,624	45,346	0	0	13	28
1986	1,380	4,693	14,004	50,255	99	227	112	255
1987	1,556	5,616	15,560	55,871	174	402	286	657
1988	1,487	5,120	17,047	60,991	201	675	487	1,332
1989	1,316	4,582	18.363	65,573	297	947	784	2,279
1990	1,611	5,864	19,984	71,437	520	2,072	1,304	4,351
1991	1,415	4,990	20,390	76,427	408	1,461	1,712	5,812
1992	1,359	4,699	22,749	81,126	596	2,120	2,308	7,932
1993	1,575	5,710	24,324	86,836	676	2,503	2,984	10,435
1994	1,401	4,837	25,726	91,673	641	2,204	3,625	12,639
1995	1,371	4,839	27,097	96,512	766	2,567	4,391	15,206
1996	1,618	5,814	28,715	102,326	1,050	3,745	5,441	18,951
1997	1,388	4,745	30,103	107,071	941	3,062	6,383	22,013
1998	1,336	4,754	31,439	111,825	1,051	3,828	7,434	25,841
1999	1,717	6,010	33,156	117,835	1,481	5,232	8,916	31,073
2000	1,397	4,864	34,553	122,699	1,203	4,140	10,118	35,213
2001	1,302	4,674	35,856	127,373	1,191	4,282	11,308	39,495
2002	1,632	5,817	37,489	133,190	1,548	5,586	12,857	45,081
2003	1,371	4,735	38,859	137,925	1,273	4,523	14,130	49,604
2004	1,455	5,228	40,315	143,153	1,260	4,443	15,391	54,047
2005	1,564	5,541	41,880	148,694	1,498	5,397	16,389	59,444
2006	1,651	6,233	43,531	154,927	1,191	4,088	18,080	63,532
2007	1,679	5,783	45,209	160,710	1,262	4,567	19,342	68,099
2008	2,245	8,278	47,454	168,988	1,104	3,579	20,446	71,678
2009	1,152	3,486	48,607	172,492	806	2,676	21,312	74,354
2010	906	3,195	49,512	175,669	638	2,332	21,889	76,686
2011	958	3,592	50,741	179,261	641	2,207	22,531	78,893
2012	752	2,475	51,223	181,736	397	1,454	22,927	80,347
2013	567	2,342	51,789	184,078	436	1,701	23,163	82,048
2014	714	2,640	52,504	186,718	572	2,313	23,936	84,361
2015	506	1,907	53,011	188,625	282	950	24,218	85,311
2016	614	2,264	53,624	190,889	355	1,354	24,572	86,647
2017	561	2,239	54,188	193,128	262	1,121	24,853	87,786
2018	270	690	54,454	193,318	181	497	25,015	88,283
2019	189	761	54,643	194,579	87	201	25,102	88,484
2020	129	326	54,773	194,905	57	133	25,160	88,617
2021	214	503	54,987	195,408	136	326	25,296	88,943
2022	168	386	55,155	195,794	0	0	25,296	88,943
2023	0	0	55,155	195,794	0	0	25,296	88,943

[a] Storage required outside of existing reactor basins.

Table F-2.—Spent Fuel Storage Projections: Total Light-Water Reactors With Construction Permits

Year	Annual discharge		Cumulative inventory		Annual storage[a] requirements		Cumulative storage requirements	
	Tonnes	Assemblies	Tonnes	Assemblies	Tonnes	Assemblies	Tonnes	Assemblies
1982	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	193	708	193	708	0	0	0	0
1985	515	1,809	708	2,517	0	0	0	0
1986	831	3,032	1,539	5,549	0	0	0	0
1987	936	3,365	2,475	8,914	0	0	0	0
1988	1,265	4,266	3,740	13,180	0	0	0	0
1989	1,256	4,066	4,996	17,246	46	252	46	252
1990	1,627	5,419	6,623	22,665	0	0	46	252
1991	1,517	5,177	8,140	27,842	74	318	120	570
1992	1,478	4,887	9,618	32,729	46	252	166	822
1993	1,508	5,269	11,126	37,998	64	150	230	972
1994	1,511	4,978	12,637	42,976	151	498	381	1,470
1995	1,549	5,256	14,186	48,232	253	827	635	2,297
1996	1,522	5,139	15,708	53,371	348	1,399	982	3,696
1997	1,525	5,169	17,233	58,540	343	1,214	1,325	4,910
1998	1,608	5,393	18,841	63,933	485	1,944	1,810	6,854
1999	1,502	4,920	20,343	68,853	501	1,869	2,311	8,723
2000	1,519	5,332	21,862	74,185	620	2,615	2,931	11,338
2001	1,478	4,765	23,340	78,950	584	2,214	3,515	13,552
2002	1,594	5,464	24,934	84,414	868	3,207	4,382	16,759
2003	1,581	5,473	26,515	89,887	933	3,472	5,316	20,231
2004	1,479	4,773	27,994	94,660	952	3,264	6,268	23,495
2005	1,569	5,395	29,563	100,055	1,159	4,104	7,427	27,599
2006	1,481	4,917	31,044	104,972	1,141	3,898	8,568	31,497
2007	1,608	5,384	36,252	110,356	1,339	4,539	9,907	36,036
2008	1,486	5,040	34,138	115,396	1,279	4,426	11,185	40,462
2009	1,504	5,144	35,642	120,540	1,345	4,709	12,530	45,171
2010	1,609	5,398	37,251	125,938	1,406	4,789	13,936	49,960
2011	1,501	4,916	38,752	130,854	1,368	4,626	15,303	54,586
2012	1,548	5,388	40,300	136,242	1,376	4,954	16,679	59,540
2013	1,838	6,119	42,138	142,361	1,366	4,575	18,046	64,115
2014	1,480	4,996	43,618	147,357	1,173	3,953	19,218	68,068
2015	1,663	6,218	45,281	153,575	1,301	4,401	20,519	72,469
2016	1,220	3,788	46,501	157,363	1,173	3,639	21,691	76,108
2017	1,367	4,519	47,868	161,882	1,311	4,397	23,002	80,505
2018	1,540	5,146	49,408	167,028	1,285	4,223	24,286	84,728
2019	1,308	3,988	50,716	171,016	1,098	3,516	25,384	88,244
2020	1,310	4,070	52,026	175,086	1,079	3,550	26,463	91,794
2021	1,017	3,320	53,043	178,406	991	3,262	27,454	95,056
2022	1,207	3,591	54,250	181,997	997	3,109	28,451	98,165
2023	1,638	6,333	55,888	188,330	961	3,426	29,412	101,591
2024	1,288	4,025	57,176	192,355	871	2,705	30,283	104,296
2025	1,027	3,299	58,203	195,654	1,027	3,299	31,310	107,595
2026	788	2,584	58,991	198,238	788	2,584	32,098	110,179
2027	669	2,014	59,660	200,252	669	2,014	32,767	112,193
2028	577	2,225	60,237	202,477	577	2,225	33,344	114,418
2029	104	193	60,341	202,670	104	193	33,448	114,611
2030	0	0	60,341	202,670	0	0	33,448	114,611

[a] Storage required outside of existing reactor basins.

Appendix G

Repository or MRS Loading Capacity Required To Remove Spent Fuel From Reactor Sites Within 10 and 15 Years After Reactor Decommissioning

Practically all of the spent fuel discharged by the end of this century is likely to still be in storage at that time, most likely storage basins at the sites of the reactors that produced it. The possibility of further delays in the availability of reprocessing or disposal facilities has led to concern that existing reactor sites might become de facto long-term repositories. This appendix is an effort to estimate how long spent fuel might have to remain at reactor sites if geologic repositories (or alternative Federal waste management facilities) do not become available until the high-confidence dates discussed in chapter 6—2008 and 2012 for the two geologic repositories, or as late as 2012 for both of two monitored retrievable storage (MRS) facilities. For purposes of comparison, the Nuclear Regulatory Commission (NRC) has determined that spent fuel can be stored at reactor sites "safely and without significant environmental impacts" for at least 30 years after the reactor ceases operation.[1]

There are two key determinants of the time spent fuel would have to remain at reactor sites: 1) the maximum rate at which spent fuel can be unloaded from storage at reactor sites; and 2) the maximum rate at which it can be loaded at Federal waste management facilties. This analysis assumes that a loading rate of 3,000 tonnes per year (tonnes/yr) can be achieved for either a geologic repository or an MRS facility. Consequently, the feasible loading schedule is primarily determined by the dates on which such facilities become available. The curves bounding area "C" in table G-1 show the total cumulative loading capacity that will be available if two 3,000-tonnes/yr repositories or MRS facilities begin operating in 2008 and 2012, or if both begin operating (upper bound) in 2012 (lower bound).

The other crucial assumption in these calculations is the rate at which spent fuel can be removed from reactor sites. A precise analysis of achievable reactor unloading scenarios would require a detailed evaluation of the conditions at each reactor, an analysis that was beyond the scope of this study. To estimate a reasonable upper bound of the time it would take to unload reactor sites, OTA made the following assumptions:

1. *Only legal weight truck casks are used.* This is a conservative assumption, since many reactors have a railroad spur that would allow the use of rail casks with a much larger capacity than truck casks.
2. *No rod consolidation is done at the reactor site prior to shipment.* This also adds conservatism, because consolidation (which may prove to be an economically attractive means of providing additional storage capacity) could increase the amount of spent fuel in each cask and thus reduce the number of shipments needed to remove a given amount of fuel from the reactor site.
3. *The truck casks are designed for fuel that is at least 10 years old.* Existing casks are designed for very hot spent fuel; casks designed for fuel that is at least 10 years old could hold about twice as much spent fuel as current designs (see ch. 3). Thus a legal weight truck cask opimized for unconsolidated older spent fuel could hold two pressurized-water reactor (PWR) assemblies (about 0.9 tonne), or perhaps four boiling water reactor (BWR) assemblies (about 0.75 tonne). Existing casks, by comparison, hold only one PWR assembly or two BWR assemblies.

   This assumption does not add conservatism, but it appears to be quite reasonable in view of the economic incentives to increase cask capacity where possible.
4. *All spent fuel must be loaded into transportation casks using the existing handling facilities the reactor site.* This is also a conservative consumption, since some technologies for additional on-site storage would allow the stored fuel to be shipped without first returning to the reactor's water basin for loading into transportation casks. If such technologies are used, the result would be a higher total rate at which fuel can be removed from the site.

Using these assumptions, an unloading rate of 100 to 150 tonnes/yr appears technically feasible at most reactors. A recent study of spent fuel transportation options for several Tennessee Valley Authority reactors

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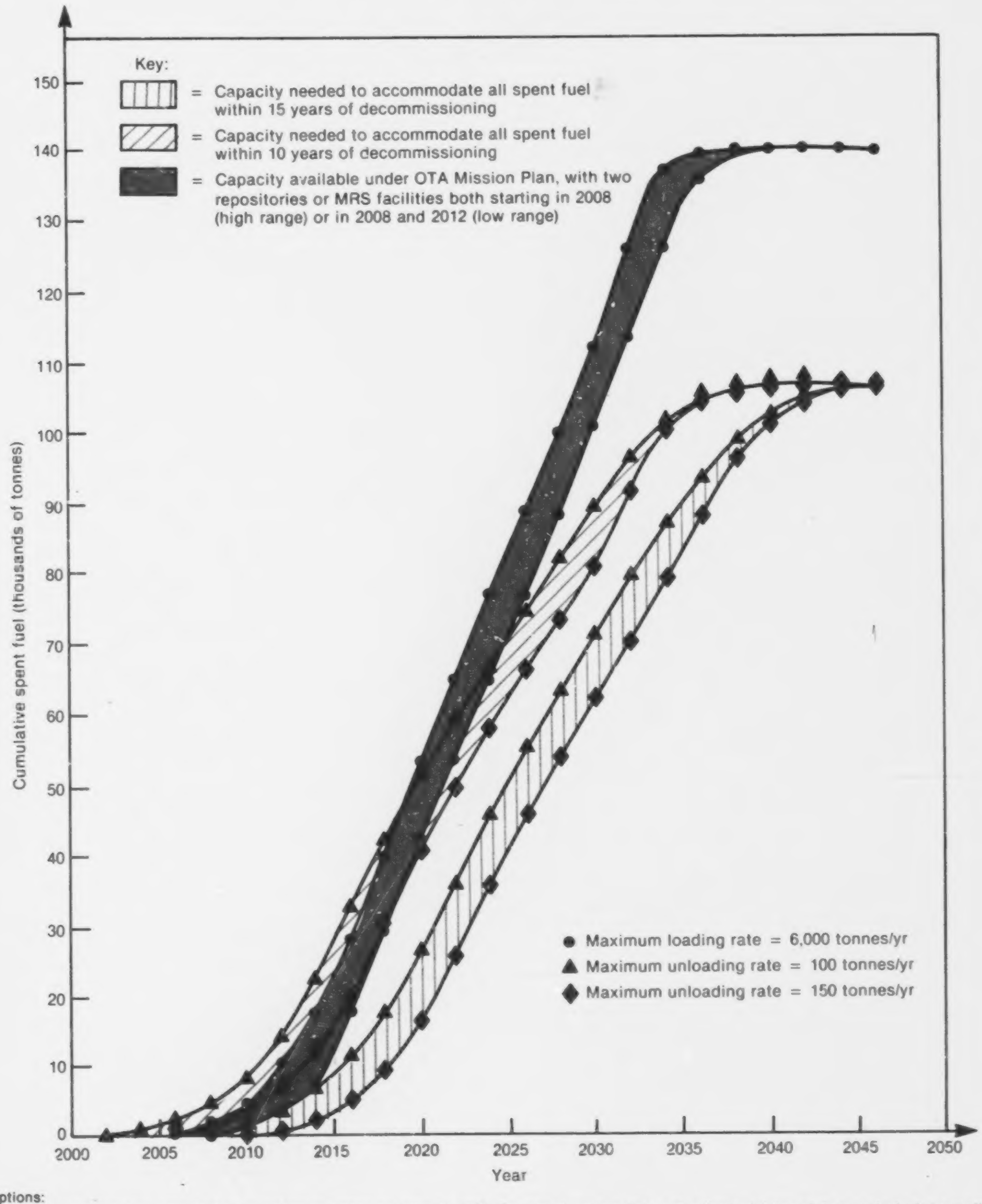
[1] U.S. Nuclear Regulatory Commission, "10 CFR Parts 50 and 51: Waste Confidence Decision," *Federal Register*, vol. 49, No. 171 (Aug. 31, 1984), p. 34660.

Figure G-1.—Spent Fuel Loading Scenarios



Assumptions:

1. Projections are for reactors operating or under construction on June 31, 1984. Reactor discharge data and estimated dates of decommissioning supplied by U.S. Department of Energy.
2. Shared basins are assumed to be unloaded after the last reactor using the basin is decommissioned.
3. For 4 reactors reaching end-of-life before 1998, decommissioning is assumed to occur in 1998.
4. Repositories or MRS facilities achieve a loading rate of 3,000 tonnes per year in 4 years, beginning with 375 tonnes the first year, 750 tonnes the second, and 1,500 tonnes the third.
5. Repository or MRS capacity assumed to be 70,000 tonnes each.

SOURCE: Office of Technology Assessment.

(including both BWRs and PWRs) indicates that about 16 hours, or two 8-hour work shifts, would be required to load one truck cask using the existing reactor facilities.[2] If only one truck cask were loaded at a time (in some cases, twp or three could be loaded at once without a proportionate increase in time), and each held about 0.75 tonnes (BWR assemblies), it would take 200 shipments each year to achieve a 150-tonnes/yr unloading rate. While this could not be accomplished using only one shift per day, it appears possible with double-shifting. Since a rate of 100 tonnes/yr would require 133 shipments (or 266 8-hour shifts), that rate might be accompished with only one shift per day.

Regulations limiting the annual radiation exposure of workers might become a constraint for such large numbers of shipments per year, even if the technical ability exists. If so, this would have to be taken into account in determining the desired unloading rate for those reactors where this problem was encountered. The amount of worker exposure may also depend on whether all spent fuel has to be returned to the reactor's storage basin for loading into transportation casks. Thus, it could be an additional reason why the choice of technologies for out-of-basin storage would significantly affect the achievable reactor site unloading rate, as discussed below.

The curves bounding areas "A" and "B" in figure G-1 show the cumulative amounts of spent fuel that would have to be shipped from reactors to enable all fuel to be removed from each reactor site within 10 years (area "B") or 15 years (area "A") after the currently projected dates of decommissioning of the reactors, using two assumed unloading rates for each reactor (100 tonnes/yr and 150 tonnes/yr) to define the upper and lower bounds. Where two or more reactors share storage facilities, shipment is assumed to begin when the last reactor using the facilities is decommissioned. **The lower the achievable unloading rate, the soonerr offsite loading capacity will be required to allow spent fuel to be removed from reactor sites within a specified period.**

Area "B" shows that if a 150-tonne/yr average unloading rate can be achieved for each reactor (lower bound), it is not necessary to start removing spent fuel from reactor sites until 2007 in order to complete the process for each reactor within 10 years of expected decommissioning (with the exception of the four reactors reaching end-of-life before 1998). If the maximum achievable unloading rate is 100 tonnes/yr (upper bound), it would be necessary to start shipments in 2001 in order to remove spent fuel from all sites within 10 years of decommissioning. To unload sites within 15 years of decommissioning (area "A"), shipments need not begin until 2006 (at 100 tonnes/yr) or even 2012 (at 150 tonnes/yr).

If a first repository or MRS facility begins loading at the rate of 3,000 tonnes/yr in 2008 ("C" upper bound), by the end of 2009 it will have exceeded the cumulative loading capacity needed to remove spent fuel from reactors within 10 years of decommissioning if the unloading rate is 150 tonnes/yr ("B" lower bound), or within 15 years regardless of unloading rate ("A"). If the second repository is available by 2012, their combined cumulative loading capacity by 2019 would exceed the amount needed for the most extreme case—unloading all reactors within only 10 years of decommissioning, at an average rate of only 100 tonnes/yr at each reactor ("B" upper bound).

Even if the two 3,000-tonne/yr facilities did not begin loading until 2012 ("C" lower bound), they could still accept the spent fuel from practically all reactor sites within 15 years of decommissioning at an average 150-tonne/yr unloading rate per reactor ("A" lower bound). If reactor sites could only unload at 100 tonnes/yr, by the end of 2015 the two facilities would exceed the cumulative loading capacity required to remove spent fuel from reactors within 15 years of decommissioning ("A" upper bound), although some reactors that would have to begin unloading before that date to meet this goal. Two facilities that begin loading in 2012 would not allow all reactors to be unloaded within 10 years of decommissioning, although their combined capacity would catch up with demand by 2020 or 2025, even in the most extreme case ("B" lower and upper bounds, respectively). Some spent fuel would have to remain in storage at a few reactor sites for 15 or 20 years.

These calculations are intended only as an approximate assessment of the implications of the high-confidence repository loading schedule in chapter 6: geologic repositories available in 2008 and 2012, or two alternative waste management facilities available in 2012 in the event of unexpected problems with geologic disposal. This analysis suggests that the postulated repository schedule would allow spent fuel to be removed from practically all reactor sites within 10 to 15 years of expected decommissioning, and the postulated backup facility schedule would allow removal within about 15 years for most reactors. **In either case, it appears possible to remove spent fuel from reactors sites well within the 30-year period during which NRC has determined that spent fuel could safely be stored at the sites after the reactors are decommissioned.**

This analysis also indicates that the choice of technologies for out-of-basin storage may have important implications for the achievable annual unloading rate.

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[2] Boeing Nuclear Power Systems, Inc., *Spent Fuel Shipping Cask Design and Transport Study*, D275-50002 (prepared for TVA under contract No. TV51222A), March 1981, pp. 54-61.

With some technologies, such as the drywell, fuel assemblies stored outside the basin would have to be returned to the basin to be loaded into shipping casks. As a result, the handling facilities at the basin could become a major bottleneck. With other technologies, such as the horizontal concrete cask concept being demonstrated by Carolina Power and Light in cooperation with the Department of Energy, stored fuel could be moved directly from the storage module into a transportation cask. If combination storage/transportation or "universial" casks prove feasible, the fuel would be stored in the cask that is ultimately used for transportation, so that no transfer from a storage facility to the transportation cask is required. In such cases, the potential bottleneck of existing handling facilities could be avoided. In addition, such technologies could reduce the worker exposures involved in unloading the stored spent fuel, thus avoiding another potential constraint on unloading rates.

Because these individual storage decisions could constrain the long-term reactor unloading plan, it is important that the analysis of an optimized system design (discussed in ch. 6) be completed quickly, before utilities have made irreversible storage decisions. It is also important to complete and evaluate the demonstrations of at-reactor dry storage technologies to determine the feasibility of those concepts that would allow spent fuel to be transported from the site without first returning to the reactor basin.

Appendix H

Glossary, Acronyms, and Abbreviations

actinides: elements with atomic numbers beween 89 and 103 inclusive; all actinide isotopes are radioactive

activation: the process of making non-radioactive material radioactive by bombardment with neutrons, protons, or other nuclear particles

activity (radioactivity): the rate at which radioactive material emits radiation, given in terms of the number of nuclear disintegrations occurring in a unit of time; the common unit of radioactivity is the curie (Ci)

AEC: Atomic Energy Commission; most of its functions have been assumed by DOE and NRC

AFR: away-from-reactor storage

AGNS: Allied-General Nuclear Services, Inc.

ALARA: as low as reasonably achievable; the principle that specifies that all radiation doses are to be maintained as far below prescribed standards as is reasonably achievable. This is a requirement for all Nuclear Regulatory Commission licensees

alpha particle: a positively charged particle emitted by certain radioactive material, made up of two neutrons and two protons; it is identical to the nucleus of a helium atom. An alpha particle cannot penetrate clothing or the outer layer of human skin

aquifer: a water-bearing layer of permeable rock or soil

at-reactor: refers to storage in the originally designed basin or to another storage facility added later; usually the latter definition pertains

atomic number: the number of protons within the atomic nucleus of each chemical element

background radiation (natural): nuclear radiation due to the natural environment and to naturally occurring radioactivity within the body

banking (of sites): setting aside public lands for possible future use

basalt: a fine-grained igneous rock, usually formed by lava flows

beta particle: a negatively charged particle emitted in the radioactive decay of certain nuclides; a free electron; it has a short range in air and low ability to penetrate other materials

biosphere: the part of the earth in which life exists, including the lithosphere, hydrosphere, and atmosphere

BLM: Bureau of Land Management, DOI

burnup: a measure of reactor fuel consumption expressed as the percentage of fuel atoms that have undergone fission, or the amount of energy produced per unit weight of fuel

BWR: boiling water reactor

byproducts: 1) any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the production or utilization of special nuclear material, i.e., fission products and/or activation products; 2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. This second category has been added by the Uranium Mill Tailings Act of 1978.

canister: a container for radioactive solid waste forms

cask: a container that provides shielding during transportation of canisters of radioactive materials

CFR: Code of Federal Regulations

cladding: the outer jacket of nuclear fuel elements which contains and supports the fuel material, protects the fuel from interaction with the coolant, and prevents the release of fission products into the coolant; commercial power reactors use a zirconium alloy for cladding, while special purpose reactors frequently use aluminum

Climax Spent Fuel Test Facility: this facility is at the 1,400-ft depth in the Climax Stock granite formation on the Nevada Test Site. Eleven encapsulated commercial spent fuel assemblies and 26 auxiliary electric heaters have been emplaced in three parallel shafts to simulate repository conditions. The test will determine the generic behavior of granite under the influence of heat and radiation

co-located: refers to location of facilities at a common site, thereby minimizing transportation needs

consolidation (compaction): reduction in the spacing of racks that hold spent fuel in a water storage basin so that the basin can hold more fuel and still remain subcritical

contamination: the deposition of radioactive material on a surface

criterion: a standard rule or test on which a judgment or decision may be based

critical mass: the minimum mass of fissionable material that, with appropriate geometrical arrangement and material composition, will sustain fission

criticality: state of being critical; a self-sustaining neutron chain reaction in which the number of neutrons lost by absorption or leakage just equals the number produced by the fission process

curie: the unit of radioactivity, abbreviated Ci. One curie equals 3.700×10^{10} nuclear transformations per second

daughter product: nuclides resulting from the radioac-

SOURCE: Adapted from U.S. Department of Energy, *Information Base for Commercial Radioactive Waste Management*, DOE/ET/40110-1, July 1982.

tive decay of other nuclides. A daughter product may be either stable or radioactive

decommissioning: the process of removing a facility from operation; its contents may be entombed, decontaminated and dismantled, or converted to another use

decontamination: the removal of unwanted material (especially radioactive material) from the surface or from within another material

deep-well injection: pumping waste-containing slurries or liquids into subterranean voids or porous strata

defense waste: radioactive waste due to research and development on weapons, the operations of naval reactors, the production of weapons materials, or the reprocessing of defense nuclear fuel

DEIS: Draft Environmental Impact Statement

deuterium: a natural isotope of hydrogen with one neutron and one proton in its nucleus (atomic weight = 2)

disposal: operations designed to provide final isolation—with no provision for easy recovery of the emplaced waste—by relying on a combination of manmade and natural barriers rather than on continuous human control and maintenance to ensure the isolation of the waste; NWPA specifies emplacement in mined geologic repositories. While disposal sites and facilities must be designed to provide disposal, as just defined, they may also be used for storage or other activities prior to disposal

DOE: U.S. Department of Energy

DOI: U.S. Department of the Interior

dome, salt: a diapiric or piercement structure with a central, nearly circular salt plug, generally one to two kilometers in diameter, that has risen through the enclosing sediments from a deep mother bed of salt

DOT: U.S. Department of Transportation

EA: Environmental Assessment

EIS: Environmental Impact Statement

emplacement medium: the material (e.g., granite or salt) in which a repository is built and into which the waste will be placed

enriched uranium: uranium in which the percentage of the fissionable isotope U^{-235} has been increased above the 0.7 percent normally found in natural uranium

EPA: U.S. Environmental Protection Agency

ERDA: U.S. Energy Research and Development Administration, now DOE

Federal repository: see repository

FEIS: Final Environmental Impact Statement

FEMA: Federal Emergency Management Agency

fertile atoms: nonfissile isotopes, notably uranium-238, which after absorbing a neutron will subsequently decay to fissile isotopes like plutonium-239

FGEIS: Final Generic Environmental Impact Statement

final isolation: placement of radioactive material in a final resting place so that removal to another site is neither necessary nor expected for as long as it takes for the material to decay to a prescribed low level of radioactivity. Synonymous with permanent isolation and terminal isolation

fissile material: one of several actinides which undergo fission when a thermal neutron is captured

fission (nuclear): the splitting of a heavy nucleus into two or more radioactive nuclei, accompanied by the release of a large amount of energy and generally one or more neutrons. Fission is usually initiated by neutrons, but it can also occur spontaneously

fission products: a general term for the complex mixture of nuclides produced as a result of nuclear fission. Most, but not all nuclides in the mixture are radioactive and decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains about 200 different isotopes of over 35 elements

fissionable material: any material fissionable by neutrons, such as certain isotopes of uranium and plutonium

fuel (nuclear reactor): fissionable material used as a source of power when placed in a critical arrangement in a nuclear reactor

fuel assembly: a grouping of fuel rods which is not taken apart during the charging and discharging of a reactor core

fuel cycle: the uranium fuel cycle to support the operation of light water reactors involves a number of stages, including: mining, milling, conversion (U_3O_8 to UF_6), enrichment, fuel fabrication, nuclear reactor operation, fuel reprocessing, waste management, and transportation between stages

fuel element: a tube, rod or other form into which fuel material is fabricated for use in a reactor

fuel reprocessing plant: a chemical plant where irradiated fuel elements are processed to separate fission products from uranium and plutonium

fuel residue waste: solid wastes consisting of the residue (fuel element hardware and chopped cladding material) after the bulk of fuel core material, including most of the actinides and fission products, has been dissolved in nitric acid in a chop and leach process. It is contaminated with low levels of actinides and fission products and contains nearly all the activation products formed in the hardware and cladding material

full-core reserve: space reserved in the reactor basin to accommodate all of the fuel contained in the reactor

full cost recovery: includes charges to the user that compensate the government for budgetary spending, for capital and operating costs, for return on invested capital, and for costs to cover unusual hazards, e.g., insurance premiums, premium pay for hazardous work, workmen's compensation

FY: fiscal year

gamma rays: short-wavelength electromagnetic radiation emitted in the radioactive decay of certain nuclides. Gamma rays are highly penetrating

GEIS: Generic Environmental Impact Statement

geologic disposal: disposal in a repository constructed in a geologic formation

GESMO: Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors, NUREG-0002

granite: a generally light-colored, coarse-grained igneous rock with substantial amounts of quartz and feldspars rich in sodium and potassium

groundwater: water that exists or flows in a zone of saturation between land surfaces

GWe: gigawatts electric, i.e., 1 billion (10^9) watts or 1,000 megawatts

half-life: time required for a radioactive substance to lose 50 percent of its activity by decay. After a period equal to 10 half-lives, the radioactivity has decreased to about 0.1 percent of its original value

head end of the fuel cycle: mining, milling, enrichment, and fabrication of UO_2 fuel

high-level waste (HLW): highly radioactive material resulting from chemical processing of spent fuel to recover usable uranium and plutonium; contains fission products, traces of uranium and plutonium, and other TRU elements. Originally produced in liquid form, HLW must be solidified before disposal

high-level radioactive waste: high-level liquid wastes, products from solidification of high-level liquid waste, and irradiated (spent) fuel elements, if discarded without reprocessing

hydrofracture: a process of producing underground openings by injection of fluids (usually water) at pressures greater than the weight of the overlying rock and soil

IAEA: International Atomic Energy Agency—established as an autonomous member of the United Nations, the IAEA currently includes over 100 participating countries. It is located in Vienna, Austria

ICRP: International Commission on Radiological Protection—located in Sutton, Surrey, England

igneous: rock formed through solidification of partially molten materials

immobilization: treatment and/or emplacement of wastes to impede their movement

induced radioactivity: radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of radioactive nuclei

INEL: Idaho National Engineering Laboratory—near Idaho Falls, Idaho

INFCE: International Nuclear Fuel Cycle Evaluation—established in 1977, INFCE includes approximately 50 countries and four international agencies. The purpose of the INFCE was to prepare an evaluation of the nuclear fuel cycle. The final report was issued in March 1980

in-situ: in the natural or original location

interim storage: temporary storage with the intention and expectation that radioactive materials will be removed for subsequent treatment, transportation, or isolation. Limited interim storage is defined by the Nuclear Regulatory Commission (NRC) as 20 years renewable at the option of NRC. Extended interim storage would be such storage for a very long (30 + years) and relatively open-ended, undefined period.

IRG: Interagency Review Group on Nuclear Waste Management—established by President Carter (March 1978) to formulate recommendations for the management of radioactive waste. Chaired by DOE, the IRG included 14 Federal agencies

irradiation: exposure to any form of radiation

isolation: the placement of radioactive materials so that contact between the waste and humans or the environment is highly unlkely for a specified period of time

isotopes: atoms of the same element which contain different numbers of neutrons in their nucleus. Isotopes which decay spontaneously emitting radiation are called radioisotopes.

kilo: a prefix indicating 1,000 (10^3) times the affixed unit, abbreviated (k)

kilogram: kg = 1,000 grams = 2.2 pounds

kWh: kilowatt-hour, a unit of energy generation or consumption in a given hour

leaching: the process of extracting a soluble component from a solid by the percolation of a solvent, such as water, through the solid

long-lived nuclides: radioactive isotopes with half-lives greater than 30 years

low-level waste (LLW): radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954, amended

LWR: light water reactor

metric ton (MT or tonne): unit of weight; 1 MT = 1,000 kilograms = 2,205 pounds

mill tailings: see uranium mill tailings

mrem: millirem, one-thousandth of a rem

MTHM: metric tons of heavy metal (nuclear fuel)

MTU: metric tons of uranium

monitoring: measuring the quantity and type of discharges or migration of radioactive waste from a waste management facility, chemical, or biological characteristics of the site and the surrounding area

MOX: mixed oxide fuel (uranium and plutonium oxides)

MRS: monitored retrievable storage

multibarrier: a system using the waste form, container, canister, overpack, and emplacement medium as multiple barriers to isolate the waste from the biosphere

MWe: megawatt electric (1 MW = 1 million watts), a unit of the rate of energy production or consumption

MWt-d/MTHM: megawatt (thermal) days per metric ton of heavy metal, a measure of burnup

nanocurie (nCi): one billionth of a curie (10^{-9}Ci), equivalent to 37 disintegrations per second

NAS: National Academy of Sciences

NASA: National Aeronautics and Space Administration

NCRP: National Council on Radiation Protection and Measurement—located in Bethesda, Md., this is a nongovernmental not-for-profit council chartered by Congress

NEPA: National Environmental Policy Act of 1969

neutron: an uncharged particle in a nucleus; of slightly greater mass than a proton; highly penetrating. Unlike the absorption of alpha, beta, or gamma radiation, the capture of neutrons by a substance can cause this substance to become radioactive

NFS: Nuclear Fuel Services, Inc.

NRC: Nuclear Regulatory Commission

NTS: Nevada Test Site

nuclear radiation: particulate and electromagnetic radiation omitted from nuclei. Important nuclear radiations are ionizing radiations

nuclear reaction: neutron reactions with materials that cause fission with the simultaneous release of energy

nuclear safety: the application of technical knowledge and administrative control to prevent an unplanned, uncontrolled nuclear chain reaction

nuclear waste: this term is usually used interchangeably with radioactive waste (see waste, radioactive)

nucleus: the inner core of an atom, consisting primarily of neutrons and protons, which makes up almost the entire mass of the atom, but only a minute part of its volume

nuclide: an atom characterized by the number of neutrons and protons and sometimes by the energy state in its nucleus

OCRWM: Office of Civilian Radioactive Waste Management, DOE

ONWI: Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio

ORNL: Oak Ridge National Laboratory

overpack: secondary or additional external containment of packaged radioactive waste

partition: to separate one element from others; in processing operations, the separation of elements such as uranium and plutonium

permanent storage: storage used as a means of providing final isolation, with no intentions of ever retrieving the waste

plutonium: a radioactive element with an atomic number of 94. Its most important isotope is fissionable Pu-239, produced by neutron irradiation of U-238

PNL: Pacific Northwest Laboratory—operated by Battelle Northwest Laboratories at Richland, Wash.

pool: a concrete chamber filled with water to provide shielding for irradiated fuel elements

PWR: pressurized water reactor: a reactor system that uses a pressurized water primary cooling system; steam formed in a secondary cooling system drives turbines to generate electricity

R&D: research and development

rad: radiation absorbed dose: a unit of absorbed dose of ionizing radiation, equivalent to the absorption of 100 ergs of radiation energy per gram of absorbing material

radioactive: unstable in a manner shown by spontaneous nuclear disintegration with accompanying emission of radiation and particles

radioactive decay: the spontaneous transformation of one nuclide into another or into a different energy state of the same one, accompanied by the emission of alpha or beta particles and/or gamma rays

radioactivity: the rate at which radioactive material is emitting radiation, given in terms of the number of nuclear disintegrations occurring in a unit of time. The common unit of radioactivity is the curie (Ci)

radioisotope: a radioactive isotope of an element

radionuclide: a radioactive nuclide

RD&D: research, development, and demonstration

reactor (nuclear): a device in which a fission chain reaction can be initiated, maintained, and controlled

rem: roentgen equivalent man: a quantity used in radiation protection to express the effective dose equivalent for all forms of ionizing radiation; the dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors

reprocessing: dissolving spent reactor fuel to recover useful materials such as thorium, uranium, and plutonium. Other radioactive materials are usually separated and treated as waste

re-racking: the replacement of existing fuel storage racks in storage basins with racks of modified design to increase the amount of spent fuel that can be stored in the basins

repository (Federal): both a site and attached facilities designed for final isolation of radioactive materials

retrievability: capability to remove waste from its place in storage; the method and rate of removal and the subsequent location of the waste must satisfy retrievability criteria

risk: the product of an event's frequency and its consequence, yielding an estimate of the expected damage rate; e.g., population dose per year from a specified event

roentgen: a unit for measuring gamma or X-ray radiation; the roentgen is defined by measuring the effect of the radiation on air. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of charge in 1 cubic centimeter of dry air under standard conditions

seismicity: the tendency for the occurrence of earthquakes

shale: laminated, easily fractured sedimentary rock produced from clay

shielding: a material interposed between a source of radiation and personnel for protection against the danger of radiation; common shielding materials are concrete, water, and lead

shipping cask: a specially designed container used for transporting radioactive materials

short-lived nuclides: for purposes of waste isolation, a relative term generally defined as radioactive isotopes with half-lives no greater than about 30 years, e.g., Cs-137, Sr-90, Kr-85, H-3

spent nuclear fuel: nuclear reactor fuel that has been used to the extent that it can no longer be used in a nuclear power plant without reprocessing

storage: operations designed to provide isolation and easy recovery of radioactive materials; storage relies on continuous human monitoring, maintenance, and protection from human intrusion for a specified period of time

storage basin: a water-filled, stainless steel lined pool for the interim storage of spent fuel

technologies: specific methods for implementing concepts; an example is storing spent fuel in a metal cask

tectonics: a branch of geology dealing with the broad architecture of the upper part of the Earth's crust. Plate tectonics considers a small number (10 to 25) of large, broad, thick plates (blocks composed of areas of both continental and oceanic crust and mantle), each of which "floats" on some viscous underlayer in the mantle and moves more or less independently of the others and grinds against them like ice floes in a river

terminal isolation (final isolation): placement of high-level wastes into a repository with no intention of recovering the emplaced material in the future

ton: English unit of weight, 1 ton = 2,000 pounds (1 short ton)

tonne: metric unit of weight, 1 tonne = 1,000 kg = 2,205 pounds (1 metric ton or 1 long ton)

transmutation: conversion of one element into another by bombarding it with a nuclear particle

transportation: movement of materials between sites (intrasite movement is not considered); this includes alternative methods for packing, handling, and transporting waste materials and plutonium compounds. Concepts include all conventional methods of land and water transport required by the waste management sytem

transshipment: shipping spent fuel from one reactor basin to another reactor within the utility system with available space

TRU: transuranic

transuranic elements: elements with atomic numbers greater than 92, including, among others, neptunium, plutonium, americium, and curium

transuranic waste (TRU waste): waste materials contaminated with U-233 (and its daughter products), certain isotopes of plutonium, and with nuclides with atomic number greater than 92. In order to be classified as TRU waste, the long-lived alpha activity from subject isotopes must exceed 100 nCi/g of waste material independent of the level of beta-gamma activity. This waste, which can vary greatly in its specific gamma activity, is produced primarily from reprocessing spent fuel and from the use of plutonium in the fabrication of nuclear weapons

tritium: a radioactive isotope of hydrogen containing two neutrons and one proton in the nucleus, with an atomic weight of 3

tuff: a rock formed of compacted volcanic ash and dust; it is usually porous and often soft

USGS: U.S. Geological Survey, DOI

uranium mill tailings: waste material resulting from the processing of ores for the extraction of uranium; the word tailings means the remaining portion of metal-bearing ore after some of the uranium has been extracted

uranium: a naturally radioactive element with the atomic number 92 and an atomic weight of approximately 238. The two principal naturally occurring isotopes are the fissionable U-235 (0.7 percent of natural uranium) and the fertile U-238 (99.3 percent of natural uranium)

uranium dioxide (UO_2): stable chemical compound of uranium and oxygen; this is the compound for most power reactor fuel

waste immobilization: the process of converting waste to a stable, solid form that encases the radionuclides to prevent or slow their migration to the biosphere

waste management: the planning, execution, and surveillance of essential functions related to the control of radioactive and nonradioactive waste,including treatment, solidification, initial or long-term storage, surveillance, and isolation

waste, radioactive: equipment and materials (from nuclear operations) that are radioactive or have radioactive contamination and for which there is no recognized use or for which recovery is impractical

water basin: a specially designed and operated water pool for storing, cooling, and shielding spent fuel elements

WIPP: Waste Isolation Pilot Plant: near Carlsbad, N. Mex., a non-NRC-licensed facility for disposal of TRU wastes resulting from national defense activities and programs

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